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# OUTLINES

OF

# EXPERIMENTAL CHEMISTRY;

BEING

## A FAMILIAR INTRODUCTION

TO

## THE SCIENCE OF AGRICULTURE.

DESIGNED FOR THE USE OF

SCHOOLS AND SCHOOLMASTERS.

### BY THOMAS TATE,

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ETC. ETC.

LONDON:
LONGMAN, BROWN, GREEN, AND LONGMANS,
PATERNOSTER-ROW.
1850.

LONDON:
SPOTTISWOODES and SHAW,
New-street-Square.

# PREFACE.

This little book embodies the substance of a course of lectures on Experimental Chemistry, and its application to agriculture, which the Author has given to the students of the Battersea Training College. The first three chapters comprise a series of experiments illustrative of the fundamental principles of Chemistry, which may be performed with a very simple kind of apparatus; the fourth and fifth chapters contain a more scientific view of the subject; and the last three chapters give a short, yet perhaps sufficiently comprehensive outline of the science of Agriculture. The work is chiefly designed for the use of the Teacher,—to aid him in giving a simple experimental course of lessons to his pupils, and to render him, at the same time, qualified for affording assistance to the practical farmer. To have written less than the Author has done on this important branch of education, would have been inadequate for effecting the ends proposed; and to have written more would probably have placed the subject beyond the reach of those for whose benefit the work is intended.

With the view of realising these objects, the author has consulted the writings of Turner, Graham, Reid, R. D. Thompson, Liebig, Johnston, Solly, Hodges, Antisell, Skilling, and Low, together with the journals of different agricultural societies.

Should this little book in any degree contribute to the introduction of Experimental and Agricultural Chemistry as a branch of elementary instruction, the Author would not consider that his time had been unprofitably employed.

*Twickenham, March,* 1850.

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# OUTLINES

# OF

# EXPERIMENTAL CHEMISTRY.

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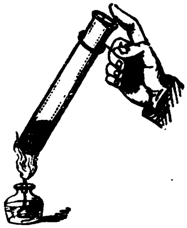
## CHAPTER I.

**NATURE OF CHEMISTRY. SIMPLE AND COMPOUND BODIES. ATTRACTION. CHEMICAL AFFINITY. NATURE OF ACIDS AND ALKALIES. SOLUTIONS.**

### NATURE OF CHEMISTRY. SIMPLE AND COMPOUND BODIES.

1. CHEMISTRY is that science which treats of the properties of the simple substances composing the globe, and of the various compounds resulting from their action upon each other. So far as our present knowledge extends, there are sixty-two simple or elementary substances, which, uniting with each other, form the vast variety of substances found in the earth, the air, and the waters of the ocean and rivers. A simple substance, do with it what we may, will not yield any other kind of substance different from itself. Thus iron is considered to be a simple body, because we can only obtain iron from it. A compound body contains two or more simple substances in a state of chemical combination. Nearly all the substances in nature are of a compound nature. Sulphur and iron are simple substances, but they combine and form a compound substance called sulphuret of iron.

*Experiment.* Take some iron-filings and mix them *intimately* with about half their weight of sulphur; put the mixture into a test-tube, and apply the flame of a spirit-lamp; at the same time close mouth of the tube with the fore-finger to exclude the air: the iron and sulphur combine with ignition, forming the compound of sulphuret of iron, a black substance entirely different from either the iron or sulphur.



2. Elementary substances are usually divided into two classes, namely, metallic and non-metallic. The following list comprises some of the most important elementary substances:—

*Non-metallic Elements.*

Oxygen,
Nitrogen, } gases found in the atmosphere;
Hydrogen, Chlorine, Carbon, Sulphur, Phosphorus Iodine, &c.

*Metals.*

Potassium, the metal which forms potassa by combining with oxygen;
Sodium, the metal which forms soda;
Calcium, the metal which forms lime;
Magnesium, the metal which forms magnesia;
Iron, Copper, Zinc, Tin, Lead, Manganese, Arsenic, Chromium, Mercury, Silver, Gold, Platinum, &c.

3. There are many substances which, although they appear simple, are in reality of a compound nature. Thus water is a compound, being made up or composed of oxygen and hydrogen; the air is chiefly a mixture of oxygen and nitrogen; common salt is a compound, containing chlorine and sodium; and so on to other cases.

## DIFFERENT KINDS OF ATTRACTION.

4. *Attraction* is one of the distinguishing qualities of *material substances.* There are various kinds of attraction.

*ttraction of gravitation.* A stone falls to the ground in *quence of* the earth's attraction, and the planets in the solar system are maintained in their orbits round the sun, by the attractive force which he exerts upon them. This is called the attraction of gravitation, and it subsists between bodies at all definite distances from each other.

5. *Magnetic attraction.* This is familiarly exhibited in the attraction which the poles of a magnet have for soft iron.

6. *Electrical attraction. Experiment.* If a stick of sealing-wax (or a glass tube) be rubbed sharply with a dry silk handkerchief, the sealing-wax will attract small cuttings of light paper: this is called electrical attraction.

7. *Attraction of cohesion. Exp.* 1. If an apple be cut in two, with a sharp knife, the pieces may be put together so as to adhere.

*Exp.* 2. Take two balls of lead; scrape a clean portion in each; bring the clean parts in contact, and rub the balls together by giving them a circular motion: they stick or cohere together.

*Exp.* 3. Two polished plates of metal placed together require considerable force to separate them.

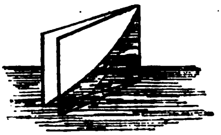
The force manifested in these experiments is called the attraction of cohesion or adhesion. The minute particles, or molecules, of which bodies are composed, are held together by the attraction of cohesion subsisting amongst these particles. Bodies are solid, liquid, or aëriform, according as the force of cohesion is modified by heat.

8. *Capillary attraction* is a peculiar form of cohesion.

*Exp.* 1. Plunge the extremity of a small glass tube in water: the fluid rises within the small bore of the tube.

*Exp.* 2. Place a piece of lump sugar on a few drops of water: the fluid rises through the fine pores of the sugar.

*Exp.* 3. Take two plates of glass, kept in contact at one extremity and a little apart at the other; plunge them into water, as shown in the figure: the water rises between the plates, forming a curved line called the hyperbola.



*These facts* are the result of capillary attraction.

### CHEMICAL ATTRACTION OR AFFINITY.

**9.** However intimately the sulphur and iron, in the experiment Art. 1. may be mixed, we can only by this means produce a mechanical mixture of the particles of the two substances; but, after chemical combination, there is no trace left of either the sulphur or the iron. Chemical affinity differs, in certain respects, from all other kinds of attraction. It resembles cohesion, inasmuch as it subsists between the particles of matter and holds them together; but while cohesion takes place between particles of the same sort, affinity is exerted between the particles of different kinds of matter; and while cohesion produces no change in the properties of a substance, affinity is almost invariably attended with a marked change in the appearance and other properties of the substances forming the compound. All chemical changes are produced by affinity or chemical attraction. Combination and decomposition are the results of chemical action.

*Combination* takes place when particles of different kinds of matter unite and form a new substance.

*Decomposition* takes place when a substance is resolved into the different kinds of matter of which it is composed or made up.

*Experiments.*

1. To a glass of water add a little oil: the oil floats upon the water, but does not combine with it. Water, therefore, has no affinity for oil.

2. Add ammonia; stir the mixture with a glass rod: the oil and the ammonia combine, and form a soapy substance, called a liniment. Oil and ammonia, therefore, have an affinity for each other. This is a case of simple combination.

3. To the soapy compound in the last experiment, add a few drops of sulphuric acid (oil of vitriol); the ammonia, *having a greater affinity* for the sulphuric acid, quits the *oil and combines* with the acid, forming the sulphate of

ammonia: the oil, being set free, again floats upon the surface. This is a case of composition as well as of decomposition: it is therefore an instance of what is called *single elective affinity.*

4. Dissolve some acetate of lead (sugar of lead) in a glass of water[*]; add a few drops of sulphuric acid: a white compound of sulphuric acid and oxide of lead is precipitated, or falls to the bottom of the glass. This is also a case of single elective affinity.

5. To a solution of acetate of lead, add a few drops of a solution of sulphate of soda (Glauber salts): sulphate of lead is precipitated, as in the last experiment, and acetate of soda remains in solution. Here there is a mutual interchange of substances: hence it is called a case of *double elective affinity.*

**10.** Compositions, as well as decompositions, are continually going on in the processes of art and nature. A piece of chalk (carbonate of lime), heated to redness in the fire, gives off a substance called carbonic acid gas, and quick lime is left. When charcoal (the *carbon* obtained from wood) is burnt away, the oxygen in the air combines with the carbon or charcoal, and forms carbonic acid gas, which is, of course, thrown into the air, and is thus apparently lost; but there is no such thing as destruction or annihilation in nature, for substances can only change their form of combination. When a piece of lump sugar is dissolved in water, the sugar, although no longer visible, is not destroyed; it has combined with the water, forming a solution of sugar. In like manner, we are able to explain all other changes of form which bodies undergo around us.

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[*] When any substance is dissolved in water, it is called a solution of that substance.

## 11. NATURE OF ACIDS AND ALKALIES.

### *Experiments.*

1. Add a few drops of sulphuric acid to a glass of water; taste the diluted acid: it is sour or acid to the taste. Add a little of the *vegetable blue* liquor of red cabbage* to a glass of water; add a little of the diluted sulphuric acid to this blue solution: it is changed to a red colour. The same experiment may be performed with any other acid.

Thus *acids are sour to the taste, and change vegetable blue colours to red.*

2. Ammonia, potassa, and soda are the most common and important alkalies. Add drop by drop of a solution of ammonia to the red liquor of the last experiment, until the red colour is changed to a greenish-blue. Taste the liquid: it is no longer sour or acid. Add now more acid, drop by drop, until the red colour is restored; and so on.

Thus *alkalies neutralise the effect of acids, and change the vegetable blues to green.*

Blue slips of paper, stained by litmus†, are usually used to ascertain when an alkali exactly neutralises an acid.

3. To liquid ammonia add sulphuric acid, until a slip of blue litmus paper, dipped into the mixture, is about to change its colour to red. This is a solution of sulphate of ammonia. Here the sulphuric acid combines with the ammonia, and forms the sulphate of ammonia, the name of the compound being formed so as to indicate its composition. In like manner, carbonic acid united to lime forms the compound of carbonate of lime; and so on to other cases.

In the same manner various other salts may be formed.

4. Take a small bit of phosphorus; set fire to it upon a piece of glass or tin placed in the centre of a common plate,

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* This is simply prepared by boiling common red cabbage, cut into small pieces, for a short time, in no more water than is just sufficient to cover them.

† Litmus is a vegetable blue.

and immediately cover it with a large dry glass. The phosphorus, as it burns, combines with the oxygen of the air, and thus forms phosphoric acid, which rises in white flakes within the glass, and finally falls upon the plate like snow. These flakes have a fine acid taste. After the ignition has ceased, pour a little water on the plate: this dissolves the flakes, and a solution of the acid is obtained.

This acid, combining with ammonia, forms phosphate of ammonia; with soda, it forms phosphate of soda; with lime, it forms phosphate of lime (which is principally the composition of bones); and so on.

5. Burn sulphur after the manner described in the last experiment. Here the sulphur, as it burns, combines with the oxygen in the air, and forms sulphurous acid, which rises, in the form of a colourless gas, into the interior of the glass. Put a violet flower (or a piece of litmus paper) into the glass: the colour is discharged. A little water poured into the plate dissolves the gas.

By a peculiar modification of this process sulphuric acid is made, which is a more powerful acid than sulphurous acid, in consequence of containing more oxygen.

## SOLUTIONS.

12. When a substance dissolves in water, the substance is said to be soluble, and we obtain a solution of it. The solution of bodies in liquids presents us with the most simple case of chemical attraction. Water readily combines with sugar, common salt, sulphuric acid, alcohol, &c.; and, on the contrary, it shows no tendency to unite with oil, ether, &c. Camphor readily dissolves in alcohol, but it is almost insoluble in water. The process of solution is much accelerated by heat and agitation. In order to obtain a concentrated solution of some substances, the liquid must be boiled

in a common oil-flask for some time with the substance. Lime is sparingly soluble in water; yet, if a little lime be added to distilled water, a sufficient portion will be dissolved to indicate the presence of lime. Distilled or pure water should be used for making solutions; however, in most cases, clean rain water will do very well.

### *Experiments.*

1. Add a small piece of camphor to alcohol or spirits of wine; stir the mixture: the camphor is soon dissolved, and a clear solution of camphor in alcohol is obtained.

Pour a little of this solution into a glass of water: the alcohol unites with the water, and leaves the camphor floating upon the surface.

2. Add a little lime to a bottle of rain or distilled water; shake it up; and, after corking the bottle, set it aside until the particles of lime have settled to the bottom: pour some of the liquid into a glass, and a clear solution of lime is obtained.

3. Dissolve a little carbonate of potassa (pearlash) in a glass of water; a clear solution of the salt is thus obtained; add a few drops of this solution to lime water: it becomes milky, owing to the formation of carbonate of lime. Here the carbonic acid, having a greater affinity for lime than it has for potassa, combines with the lime, and leaves the potassa in solution. The carbonate of lime is said to be precipitated; that is, it falls to the bottom of the glass, owing to its being nearly insoluble.

4. Breathe through a tube into a solution of lime: a milkiness is produced, owing to the formation of carbonate of lime. Here carbonic acid gas is expired from the lungs.

# CHAP. II.

## FAMILIAR EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES AND COMPOUNDS OF SOME OF THE MOST IMPORTANT SIMPLE SUBSTANCES.

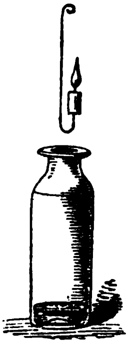
### CARBON. CARBONIC ACID GAS.

**13.** When wood is burned (as is done by the charcoal burners) in such a manner as to exclude the air, it is converted into wood *charcoal*, which is nearly pure *carbon*. The diamond is perfectly pure carbon in a crystallised form. Combined with other substances, carbon is found in vegetable, animal, and many mineral substances. When charcoal is burnt in the air it forms carbonic acid, a heavy gas, which extinguishes flame, and is destructive to animal life.

### *Experiments.*

1. Put some pieces of chalk (carbonate of lime) into a bottle with a wide mouth; add sulphuric acid (or any other strong acid): violent effervescence takes place, owing to the escape of carbonic acid gas with the formation of sulphate of lime. Here the sulphuric acid unites with the lime in the chalk, and the carbonic acid in it is set free in the form of gas.

2. In the last experiment, the carbonic acid gas, as it is formed, gradually drives out the air in the bottle, and takes its place. This gas, being colourless, cannot be distinguished from common air by the eye: its presence, however, may be detected. Plunge a burning candle into the gas: the flame is instantly extinguished, while the gas remains unchanged.



Thus *carbonic acid gas extinguishes flame, and at the same time it does not take fire,* as some other gases do.

### HYDROGEN. COMPOSITION OF WATER.

**14.** Hydrogen is a colourless, inflammable gas, and the lightest known substance in nature, it being about 14½ times lighter than air. Water is composed of hydrogen and oxygen. Hydrogen also enters into the composition of the inflammable or organic part of plants.

### *Experiments.*

1. Put a few pieces of zinc cuttings into the wide-mouthed bottle (see last fig.); pour upon them some diluted sulphuric acid[*]: the mixture soon effervesces, owing to the escape of bubbles of hydrogen gas, which gradually displace the air and fill the bottle. Cover the bottle with a plate, or with a piece of window-glass[†], to prevent the external air from mingling with the hydrogen. When a sufficient quantity has been obtained, take off the cover, and plunge a lighted candle into the gas: the flame of the candle is extinguished, but the gas takes fire and burns at the mouth of the bottle, with a pale yellow flame.

When hydrogen is mixed with common air, the ignition goes on more rapidly, and sometimes with a slight explosion; but the experiment may be made with perfect safety in the manner just described.

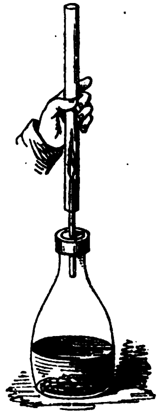
In this experiment, the sulphuric acid, the oxygen portion of the water, and the zinc, combine and form the sulphate of the oxide of zinc; which remains in solution, while the hydrogen portion of the water escapes in the form of a gas.

Thus *hydrogen burns, but does not support flame.*

---

[*] A mixture of 1 part of strong acid to about 4 or 5 parts of water.

[†] N. B. In all experiments relative to gases generated in this way, it must always be understood that a plate, or a piece of window-glass, is to be laid over the mouth of the vessel for a few seconds, in order to exclude the external air.



2. Generate hydrogen in a bottle, as in the last experiment; and, *after the air has been driven out*, close the mouth with a cork, through which the tube of a tobacco-pipe passes; light the gas as it issues from the fine opening of the tube. Insert this small flame a few inches into a glass tube, about 20 in. long and 1 in. in diameter. As the hydrogen burns, it combines with the oxygen of the air; thus water is formed, which covers the interior of the tube in the form of moisture. After a short time, the tube emits musical sounds. These sounds are produced by the air rushing in to fill up the void formed by the ignition of the hydrogen. To show the formation of water, a dry glass may be held over the flame.

## OXYGEN AND NITROGEN. THE ATMOSPHERE.

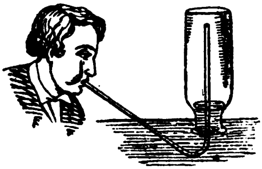
**15.** The atmosphere is a mixture of oxygen and nitrogen: there is also a small portion of carbonic acid gas *always* present in the air.

### *Experiments.*

1. Put a lighted wax candle on the table; place over it a glass jar, previously dried with care; the candle soon begins to burn dimly, as the inflammable substances in it consume the oxygen of the air, and, after a little time, the flame is extinguished; the interior of the glass will now be found covered with drops of water. Here the candle is extinguished, in consequence of the consumption of the oxygen, which, uniting with the hydrogen and carbon of the tallow, forms water and carbonic acid gas. See also Exp. 4., Art. 11.

2. Put a lighted candle (supported by a bent wire passing through a cork) into a large bottle; close the mouth of the bottle: the flame soon becomes dim, and then goes out, in consequence of the air being no longer able to support combustion. Take out the candle, rekindle it, and plunge it into the bottle : the flame is immediately extinguished.

If a living animal were confined in a close bottle, after the oxygen in the air becomes vitiated, the animal would die. A second animal, placed in this vitiated air, would at once expire.

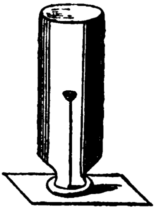


3. Take a large bottle containing common air; place its mouth in water; close the nostril with the forefinger and thumb, and inspire and expire the air in the bottle, by means of a bent pewter tube, for a few seconds. At each inspiration the water rises in the bottle, and at each expiration the water falls. Take the bottle containing the air which has thus been vitiated by passing through the lungs, plunge a lighted taper into it, as in Exp. 2.: the flame is extinguished. Here the oxygen of the air is consumed in the act of respiration, and the vitiated air returned to the bottle contains the nitrogen, which was at first in the air, mixed with carbonic acid gas. See also Exp. 4., Art. 12.

In the process of breathing, the oxygen taken from the air is returned to it in the form of carbonic acid gas; thus one great end of breathing consists in depriving the blood of its carbon or charcoal.

Thus *oxygen not only supports flame, but also animal life:* hence it is called vital air.

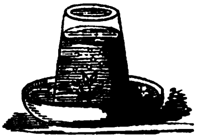
4. Place a wire, supporting a small cup, on a stand or shelf covered with water; put a small piece of phosphorus in the cup; ignite the phosphorus, and then invert a large bottle



over it. The phosphorus consumes all the oxygen in the bottle, thereby forming phosphoric acid, and leaves the nitrogen. After shaking the water in the bottle (its mouth being still kept under the water) the water rises, occupying the place of the oxygen which has been consumed. This will be found to be about $\frac{1}{5}$ of the air at first in the bottle. The residue is nitrogen gas; thus showing that $\frac{1}{5}$ of the bulk of the air is oxygen, and $\frac{4}{5}$ are nitrogen.

5. Take the bottle of nitrogen (covering its mouth with a piece of glass) and place it on the table with its mouth uppermost; plunge a lighted candle into the gas: the flame is extinguished, at the same time the gas does not take fire.

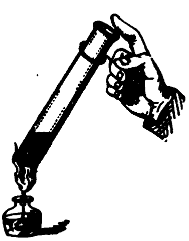
Thus *nitrogen neither supports flame, nor does it take fire as hydrogen does.*



6. Put some green leaves beneath an inverted glass filled with water, and place it in the sunshine: the leaves will be found to give off oxygen gas.

Thus *plants give off oxygen gas, while animals consume it.*

7. Introduce some chlorate of potassa in powder (a salt which contains a large quantity of oxygen) into a test-tube; apply the flame of a spirit-lamp; the salt is decomposed by the heat, all the oxygen gas being given off; apply the finger lightly to the mouth of the tube, to keep the gas as pure as possible; plunge a lighted splinter of wood into the gas; the flame is much increased in brightness; before introduction, blow the flame out so as to have a red spark remaining: the wood is instantly rekindled, thereby showing that pure oxygen is an eminent supporter of combustion.



8. Pour some lime water into a glass, and allow it to stand for a few hours : a skin of carbonate of lime is formed upon the surface. This shows that there is carbonic acid gas in the atmosphere.

### AMMONIA.

**16.** This gaseous substance is composed of nitrogen and hydrogen. Water dissolves a large quantity of this gas, and the solution is called liquid ammonia or hartshorn. It readily combines with all the acids, and forms salts of ammonia. This substance is invariably given off from animal matter in a state of putrefaction; the ammonia thus formed rises into the air, where it floats until it is washed down by the rains to fertilise the soil. It is one of the most fertilising substances found in farm-yard manure and guano.

### *Experiments.*

1. Hold test paper over a bottle of liquid ammonia: a powerful alkaline action is exhibited. Smell the ammonia; it has a strong pungent odour.

2. Dip a glass rod in hydrochloric acid, and hold it over a bottle of liquid ammonia : white fumes of hydrochlorate of ammonia are formed.

3. Take a bottle of hydrochloric acid into a horse stable; take out the stopple of the bottle : white fumes, as in the last experiment, are formed about the mouth of the bottle.

4. Take two bottles; put a little liquid ammonia into one of them, turning the bottle round so as to spread the ammonia over the interior; in like manner introduce hydrochloric acid into the other bottle; bring the mouths of the bottles together, as in the annexed cut: the dense white fumes of hydrochlorate of ammonia are produced.

5. Take equal parts of hydrochlorate of ammonia (sal-ammoniac) and quicklime, each separately powdered, and *mix them briskly* together: the strong pungent fumes of *ammoniacal gas* will be felt.

6. Perform the same experiment with a mixture of guano and quicklime: ammonia is in this case given off from the guano.

7. To a solution of carbonate of ammonia add a solution of oxalic acid until effervescence ceases : a solution of oxalate of ammonia is obtained. Here the acid and ammonia combine with the escape of carbonic acid gas.

### NITRIC ACID, OR AQUA FORTIS.

**17.** This important substance is a compound of nitrogen and oxygen. It is manufactured from nitre (nitrate of potassa), a substance composed of nitric acid and potassa. There is reason to believe that nitric acid is formed in the air during thunder-storms. Decaying organic substances containing nitrogen yield this acid. Nitric acid, as well as ammonia, supply the growing plant with nitrogen.

**18.** THE ATMOSPHERE is that vast ocean of elastic fluid which everywhere surrounds the globe, extending to the height of about fifty miles above the tops of our highest mountains. This subtle elastic fluid bears on its tide the exhalations of the earth over every clime, descends to the lowest depths of our mines, and penetrates into the recesses of our darkest caverns. Although invisible to the eye, and although bodies move through it with apparent ease, yet the chemist has weighed it in his balance, and determined its composition with an exactness which challenges dispute. Everywhere the composition of the air is the same*,—as far as regards its essential elements,—whether it be taken from the confined alleys of our crowded cities, or from the mountain tops over which the healthful winds play with unobstructed freedom. Winds, air in motion, drive our vessels through the ocean, and perform useful labour in our windmills. The atmosphere is the great agent by which heat is nearly equally distributed over the earth, and without its agency light itself would scarcely serve the purposes for which it is designed. By its means moisture is scattered over the vegetable creation in the form of rain and dew; and these rains wash down ammonia, nitric acid, and various exhalations essential to the growth of plants.

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* This arises from the diffusiveness of gases, or the tendency which they have to intermix with each other, without regard to their difference of density or heaviness.

The substances *essential* to the constitution of the atmosphere are oxygen, nitrogen, carbonic acid gas, and watery vapour. The oxygen, as we have shown, is necessary to the existence of the animal world, and to the support of combustion; while the nitrogen tends to moderate the intensity of the action of the oxygen. The comparatively small portion of carbonic acid gas in the air affords an important part of the food to the vegetable world, and the watery vapour, besides serving other important purposes, tends to keep the skin of animals and the surface of plants in a moist condition. The beautiful adjustment of the relative proportion of these substances to suit the wants of animals and plants, is a remarkable instance of the nice adaptation of means for the production of a proposed end.

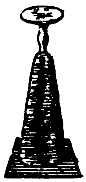
The air is being continually supplied with carbonic acid gas from the respiration of animals; from the burning of wood, coal, and other combustible bodies; and from all animal and vegetable substances in a state of decay. Farmyard manure, also, put into the soil in a fermenting state, yields an abundant supply of carbonic acid gas, as well as of ammonia, to the growing plant. The atmosphere, however, affords the chief source of carbonic acid to plants, which, assimilating the carbon, give off the oxygen into the air to make up the deficiency produced by the respiration of animals. Guided by an unseen power, one part of creation administers to the necessities of another part: thus plants and animals are necessary to each other's existence,—the one supplies what the other consumes,—what is discharged as useless from the one becomes essential food to the other. This remarkable law of compensation seems to run through the whole of the universe, and a proper appreciation of its nature cannot fail in forcibly impressing upon our minds the great and solemn fact—that the universe is the work of a Being infinite in wisdom, goodness, and truth.

Thus the atmosphere, which appears as nothing to the vulgar eye, is not less essential to the economy of nature, than the solid matter of which the globe is composed, or the great ocean of waters which float upon its surface.

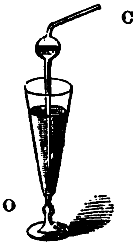
The following experiments are intended to illustrate some of the most important and familiar mechanical properties of the air, gases, and vapours.

### *Experiments, with descriptions of Apparatus.*

1. Fill a wine-glass with water, and cover the mouth with a piece of paper; place the hand over the paper, and invert the glass; take the hand carefully away: the water remains suspended in the glass by the pressure of the external air.



2. Draw water into the mouth by a tube. Here the process of sucking draws the air from the tube, and the pressure of the external air causes the water to rise in the tube. The pipette, used in many chemical experiments, depends on this principle. When the finger is placed upon the upper opening c, the fluid in the tube remains suspended; and, on the contrary, when the finger is removed, the fluid descends drop by drop from the small orifice o of the lower extremity.

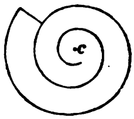


3. Fill a small-necked bottle with water; carefully invert the bottle: the water remains suspended by the atmospheric pressure.

4. Throw a piece of burning paper into a wine-glass, and while the paper is still burning forcibly close the mouth of the glass with the hand; after a few seconds, the glass will be found to stick to the hand with considerable force.

Here the heat expels nearly the whole of the air in the glass, by causing it to expand; after the air left in the glass cools, it contracts, and then the pressure of the external air upon the outside of the glass becomes greater than the pressure of the rarefied air within the glass.

5. Cut a piece of paper in the form of a spiral, as in the annexed cut; run a thread through the centre *c*; suspend the paper by this thread, and it will have something like the form of a cork-screw: bring it over a lighted candle, and the suspended paper will turn round in one certain direction. Here the heated air about the candle ascends, and impinges upon the surface of the paper, and thus causes it to revolve on the same principle as a toy windmill.

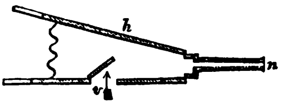


6. Invert a tall glass over water, and gradually press it down; as the glass is being pressed down, the air that is in it occupies less and less space, and the force requisite to keep the glass down, or to balance the elastic force of the air, increases with the decrease of the volume of the air in the glass. Thus *air is an elastic fluid, and its elastic force, or pressure, increases with the decrease of the space which it is forced to occupy.*

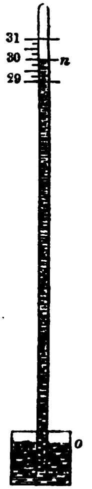
Heat, by causing air to expand, also increases its elastic force.

7. Partially fill a bladder with air; tie the mouth, and place it near a good fire; the air within the bladder expands and completely fills it.

8. Take a pair of common bellows; observe, while you raise the top board *h*, that the valve *v* opens, in consequence of the external air rushing in to fill up the void; and observe, while you depress the top board, that the valve *v* is closed, and the air is propelled through the nozzle *n* with considerable *force, in consequence* of the elasticity of the compressed air *within the bellows.*

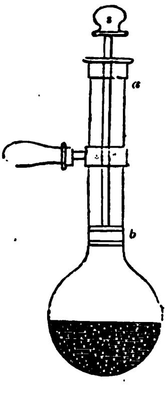


9. Take a glass tube, about 32 inches long, closed at one extremity; fill the tube with mercury, apply the finger to the open end, and immerse it in a cup of mercury; bring the tube to an erect position: a column of mercury about 30 inches high remains supported in the tube, by the pressure of the atmosphere upon the surface of the mercury in the cup. The column of mercury is estimated from *o* to *n*. The space in the upper part of the tube is a vacuum. In this manner it has been found that the pressure of the air upon every inch of surface is about 15 lbs. The action of the common pump depends upon the pressure of the atmosphere.



10. Boil some water in an oil-flask, or in a common glass retort, and while the steam issues from the mouth of the vessel, suddenly plunge the mouth into cold water; the steam is condensed,—a vacuum is produced,—and the cold water rushes into the vessel and at once fills it.

11. Apply the flame of a spirit-lamp cautiously to the bulb A of Woolaston's glass model steam engine; when the water boils, the elastic force of the steam drives up the piston *b;* when the piston has arrived at *a*, the full length of the stroke, take the model away from the lamp: the steam cools and becomes condensed,—a vacuum is formed within the tube,—and the pressure of the external air upon the piston causes it to perform a downward stroke; repeat the experiment. This beautiful experiment illustrates the fundamental principle of our steam engines.



12. Invert a bottle, F, filled with water in the same fluid; the water remains suspended in the bottle by the pressure of the

the quantity of gas that may be in the cylinder at any time. To fill the cylinder A with gas: A is first filled with water, which is done by opening the three cocks *a*, *b*, *d*, closing the aperture *h* with a cork, and pouring water into the shelf B: the water runs through the pipes *a* and *b* into A, expelling the air through *d*. When A is filled with water, the cocks *a*, *b*, and *d* are closed, and the aperture *h* is opened; the water remains in the cylinder A in consequence of the atmospheric pressure, just in the same way as water is suspended in the bird-fountain; introduce the tube proceeding from the retort into the aperture *h;* the gas will then rise in bubbles into the cylinder, displacing the water through *h*. To fill a jar B with the gas: pour water on the shelf B; open the cocks *b* and *a;* the gas then rises in bubbles into B, from the pressure produced by the column of water in the pipe *ac*. The gas may also be transferred through the cock *d*.

13. Put a few drops of water on a warm plate; the water soon disappears, the process of evaporation having carried it into the air in the form of an invisible watery vapour. Observe also how speedily the steam, as it issues from the mouth of a tea-kettle, disappears in the air.

14. Take a dry tumbler into a warm apartment; pour some cold spring water into the glass: the outside of the glass instantly becomes covered with moisture. Here the cold glass cools down the air immediately in contact with it, and thereby causes that portion of the air to deposit its moisture. Heated air can retain a larger quantity of watery vapour than cold air.

## SULPHUR.

**19.** This important elementary substance abounds, in its simple state, in the Island of Sicily, and in many volcanic countries. It is also found, in combination with iron and *copper, in many* parts of the world. Sulphuric acid is the *most important* compound of sulphur; united with various bases, such as lime, soda, magnesia, &c., it forms sulphates, which are found abundantly in the mineral kingdom.

### *Experiments.*

1. Heat sulphur in a test-tube; the sulphur first melts, and then rises in vapour, which condenses in the cold part of the tube. See also Exp. 1., Art. **1.**; and Exp. 5., Art. **11.**

2. To a solution of baryta add sulphuric acid; the white precipitate of sulphate of baryta falls, which is not dissolved by nitric acid. This is the best test for the presence of sulphuric acid.

3. Put some sulphuret of iron in a bottle, and pour some diluted sulphuric acid upon it; sulphuretted hydrogen gas is given off, which has the smell of rotten eggs; dip a slip of white paper in a solution of acetate of lead, and suspend the paper in the bottle containing the gas: the paper is rendered black from the formation of the sulphuret of lead.

*Sulphuretted hydrogen*, or *Hydrosulphuric acid*, is highly inflammable, and is much used as a test for the presence of different kinds of metals. The fumes of this gas should be avoided, as it is deleterious to animal life.*

## PHOSPHORUS.

**20.** This elementary substance is very inflammable, and therefore should be handled with great caution. It has very much the appearance and consistence of wax. It is found in urine, and enters into the composition of animal bones.

### *Experiments.*

1. Fold a thin slice of dried phosphorus in a piece of paper; rub it briskly with any smooth body: the heat produced by the friction speedily ignites the phosphorus.

2. Write upon the wall with a stick of phosphorus (wrapped round with a piece of paper); the writing appears luminous in the dark. See also Exp. 4., Art. **11.**

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* *All fumes given off by chemical action should be carefully avoided.*

3. *Phosphuretted hydrogen gas.* Put some zinc cuttings and a few small slices of phosphorus into a tumbler glass; take the glass into a dark room, and add some diluted sulphuric acid: the mixture appears like *a well of fire,* in consequence of the escape of phosphuretted hydrogen gas, which ignites spontaneously when it comes into the air.

### IODINE.

**21.** This elementary substance is solid, having a dark bluish colour, with a somewhat metallic lustre. It is found in sea-water and marine plants. It is highly soluble in alcohol, but is sparingly dissolved by water. Its most important compound is iodide of potassium, which is now much used as a medicine.

#### *Experiments.*

1. Heat one or two grains of iodine in a flask: the beautiful violet vapour of iodine rises within the flask, and slowly condenses.

2. Dissolve a *very small* piece of iodine in water; the water has a brown colour. To this solution add a *cold* solution of starch*: the beautiful blue compound of iodide of starch is formed.

3. Drop a small piece of iodine on a few grains of phosphorus: the substances combine with ignition.

4. To a *cold* solution of starch add a few drops of iodide of potassium; no action is produced: add now a little sulphuric acid to set the iodine free; the blue iodide of starch is formed.

### CHLORINE.

**22.** Chlorine is a greenish-yellow gas (hence its name) which has a pungent, suffocating odour; it is not inflammable, but it supports combustion; indeed, some bodies ignite in it spontaneously. It combines with the metals, forming chlorides; thus common salt is a chloride of sodium. With oxygen it forms acids; the most important of these is chloric acid, which, combined with potassa, forms chlorate of potassa, a salt largely employed in the manufacture of lucifer matches. Chlorine destroys all colouring matters and offensive effluviæ.

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* Starch should be dissolved in hot water.

## *Experiments.*

1. Put a table-spoonful of chloride of lime (common bleaching powder) into a bottle; add an equal bulk of hydrochloric acid; chlorine, in the form of a greenish-yellow gas, soon fills the bottle: introduce a lighted candle; it burns with a dull red-coloured flame in the gas; suspend a moistened slip of blue litmus paper (or any other coloured substance) in the gas: the paper is soon bleached by the gas.

2. To a mixture of common salt and black oxide of manganese, add sulphuric acid; chlorine gas is given off. This is a highly convenient way of using chlorine for purposes of fumigation. The chlorine destroys all noxious malaria.

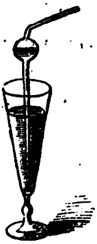
3. Add hydrochloric acid so as to cover half a tea-spoonful of chlorate of potassa in powder, in a small bottle; chlorine gas (mixed with chlorous acid) is generated; dip a slip of writing-paper into oil of turpentine, and introduce it into the gas: combustion immediately takes place. Perform the bleaching experiment described in Exp. 1.

Chlorous acid explodes with great violence, when heated even to a moderate temperature.

4. Mix a few grains of powdered lump sugar with twice the quantity of chlorate of potassa; let fall a drop of sulphuric acid on the mixture: chlorous acid is disengaged, which immediately inflames the mixture.

5. Carefully fold in a piece of paper a little chlorate of potassa in powder, with a small piece of phosphorus; strike the mixture with a hammer: a loud explosion takes place.

6. *To inflame phosphorus under water.* Put some crystals of chlorate of potassa, together with a few slices of phosphorus, into an ale-glass; fill the glass with cold water; let fall a few drops of sulphuric acid, by means of a pipette, on the chlorate of potassa: the acid takes up the potass from the salt, and sets free a compound of chlorine and oxygen, which inflames the phosphorus.



### HYDROCHLORIC ACID.

**23.** Hydrochloric acid or muriatic acid is a gas, composed of hydrogen and chlorine; it is largely dissolved by water, forming common aqueous hydrochloric acid.

*Experiment.* Add diluted sulphuric acid to common salt, in a bottle; hydrochloric acid gas is given off with effervescence, and fills the bottle; suspend a slip of moist blue litmus paper in the gas; the colour is changed to red: plunge a lighted candle into the gas; the flame is extinguished.

In this experiment, the acid decomposes the salt, which is a compound of chlorine, sodium, and water; the hydrogen of the water unites with the chlorine and forms hydrochloric acid gas; and the oxygen of the water unites with the sodium and forms soda, which combines with the sulphuric acid and forms the sulphate of soda.

# CHAP. III.

## METALS AND METALLIC OXIDES.

### POTASSA AND SODA.

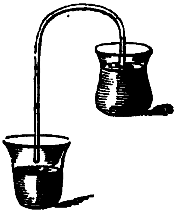
**24.** POTASSIUM and sodium, united with oxygen, form potassa and soda. These important substances are called *fixed alkalies*, to distinguish them from ammonia, which is called the volatile alkali. (See Art. **11.**) Potassa is found in the ash of plants, and soda in the salt of sea-water.

*Experiments.*

1. Throw a grain of potassium upon water; it floats on the water, and takes fire: a solution of potassa is formed, by the union of the oxygen of the water with the metal.

2. Burn some pieces of wood; collect the ashes, and pour water upon them to dissolve the potassa which is in them; add a solution of some vegetable blue: the colour is changed to green.

3. Boil, in an iron vessel, equal weights of slaked lime and carbonate of potassa (pearl ashes) in about twelve times the weight of water; the carbonic acid unites with the lime, forming the insoluble carbonate of lime, leaving the potassa in solution. Cover the mixture, and allow it to stand until the carbonate of lime subsides; draw the clear solution off by means of a syphon.* When a solution of potassa is exposed to the air, it speedily takes up carbonic acid, and returns to the state of carbonate of potassa.



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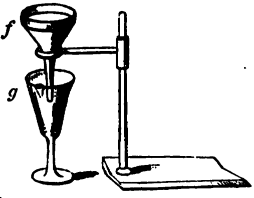

* Insoluble substances, or precipitates, are usually separated from liquids by FILTRATION, which consists in passing the liquid through *filtering paper* placed in a funnel *f*; by this process the clear liquid drops into the glass *g*, and the precipitate or insoluble substance remains on the filtering paper.

These filters are formed by making two folds, in a round piece of paper, at right angles to each other, and in a contrary direc-

4. To a strong solution of carbonate of potassa, add a solution of tartaric acid; crystals of bitartrate of potassa (cream of tartar) are formed with the escape of carbonic acid gas.

5. Boil nitrate of potassa (nitre) in water, so long as any of the salt is taken up; decant the solution, and as it cools crystals of nitre, in six-sided prisms, are deposited.

*Soda* is found in the ashes of sea-ware; it is also obtained from common salt. The compounds of soda are very similar to those of potassa.

### LIME.

**25.** Chalk, limestone, marble, lime-shell, and calcareous spar, are all compounds of lime and carbonic acid. Lime forms an essential constituent of all good soils. Mixed with vegetable or animal substances, it promotes their decay, and at the same time absorbs the noxious gases that are given off. Lime is an oxide of a metal called calcium.

### *Experiments.*

1. Expose lime-water, in an open vessel, to the air: a crust of carbonate of lime soon appears upon the surface. See also Experiments 2., 3., and 4., Art. **12.**

2. Pour hydrochloric acid upon some piece of chalk, so long as any effervescence is seen: a solution of hydrochlorate of lime is formed.

3. Make a solution of nitrate of lime, by adding nitric acid to chalk, after the manner of the last experiment.

4. Pour a little of the solution of hydrochlorate of lime into an ale-glass, and about the same quantity of strong sulphuric acid into another glass; pour the latter quickly upon the former; a violent effervescence takes place from the escape of hydrochloric acid: a solid white substance,

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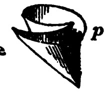
tion: when this piece of paper is placed within the funnel, it will assume the form of *p*, shown in the cut. The liquid to be filtered should be carefully poured upon the sides of the filter, so as not to injure the paper at the bottom part. Before use, the filter paper should be moistened with distilled water.



sulphate of lime, is formed. Owing to the condensation, great heat is evolved.

5. To any solution of lime add oxalate of ammonia (see Exp. 7., Art. **16.**): the white insoluble oxalate of lime falls.

### MAGNESIA.

**26.** This substance is found in sea-water, in certain varieties of limestone (magnesian limestone), and in many spring waters. Magnesia is the oxide of a metal called magnesium.

### *Experiments.*

1. To diluted sulphuric acid add carbonate of magnesia (a white powder) until effervescence ceases: a solution of sulphate of magnesia (Epsom salts) is obtained.

Boil off or evaporate a portion of the water*; set aside the solution until it cools: crystals of the salt will be formed.

2. To a solution of sulphate of magnesia add a solution of carbonate of potassa: a white precipitate of carbonate of magnesia is formed.

This distinguishes Epsom salts from oxalic acid, a poison frequently mistaken for the former. It is further to be observed, that oxalic acid is sour to the taste, whereas Epsom salts are bitter. Oxalic acid is dissipated when thrown upon hot cinders, whereas Epsom salts leave a white mass behind.

### ALUMINA.

**27.** This earth is an oxide of a metal called aluminum; it abounds in common clay. It is distinguished by its insolubility, and by being dissolved in a solution of potassa. Alum is one of its most useful and common compounds. This salt contains alumina, potassa, and sulphuric acid. Pure clay is a compound of silica and alumina: in the proportion of about 3 parts of the former to 2 of the latter.

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* Evaporations are best conducted in porcelain dishes, or, as they are called, evaporating dishes; the heat should be applied by a sand bath, or by an *Argand* lamp with a tin or copper chimney.

*Experiments.*

1. Add ammonia to a solution of alum: alumina falls, in consequence of the ammonia combining with a portion of the acid.

2. Perform the same experiment, using potassa or soda.

3. In a saturated solution of alum, suspend a basket formed of woollen thread: the alum forms beautiful crystals on the thread, thereby forming *an alum-basket.*

### SILICA.

**28.** This earth, like alumina, is very abundant in nature. Quartz is nearly pure silica, and it is the chief ingredient in sand and common flint. Mixed with clay, it forms the great body of soils. Silica is an oxide of silicon.

*Experiments.*

1. Mix one part of fine sand with three parts of carbonate of potassa; fuse the mixture in a crucible; carbonic acid is driven off, and the silica and potassa combine and form a glass, called silicated potassa, which readily dissolves in water; pour out the silicated potassa on an iron plate; dissolve a portion of it in water. This experiment is highly important, considered in relation to agricultural science.

2. To the solution of silicated potassa add a solution of hydrochlorate of ammonia; the hydrochloric acid combines with the potassa, and the silica is precipitated.

### IRON.

**29.** This valuable metal is found in a great variety of forms in nature. Combined with oxygen, it is found as an oxide of iron; with sulphur, as a sulphuret of iron; with carbonic acid, as a carbonate of iron.

*Experiments.*

1. Place some iron-filings in a saucer; moisten them

from day to day, until they become *rust*, or oxide of iron, by combining with oxygen.

2. To some iron-filings add diluted sulphuric acid: hydrogen gas is given off, and a solution of iron (green vitriol) is formed. Here the oxygen of the water combines with the iron, forming oxide of iron, which unites with the acid, forming the sulphate of the oxide of iron, or, as it is simply called, sulphate of iron.

Decant the clear solution, evaporate it, and set it aside; when the solution is cold, green crystals will appear.

3. Add a few drops of a strong solution of sulphate of iron to 4 glasses containing water:—

- I. To the first add a solution of potassa: oxide of iron falls.
- II. To the second add a solution of carbonate of potassa: carbonate of iron falls.
- III. To the third add a solution of prussiate of potassa: a fine blue precipitate of Prussian blue is formed.

In these three experiments the sulphuric acid combines with the potassa, and remains in solution.

- IV. To the fourth add an infusion of galls: the black gallate of iron, the substance which gives the colour to ink, after a few seconds appears.

4. To a glass of water add a few drops of ink; add oxalic or hydrochloric acid: the colour disappears.

5. Write on paper with a very diluted solution of sulphate of iron; when dry, the writing is invisible; wash it over with a solution of prussiate of potassa: the writing appears of a fine blue colour.

### COPPER.

**30.** This metal exists in nature in its pure or metallic state; but it is chiefly found as a sulphuret of copper (copper pyrites).

### *Experiments.*

1. *Heat* copper for some time in the fire; suddenly plunge

the heated copper into water : the oxide of copper is formed in scales on the surface of the metal.

2. Put some slips of copper into diluted nitric acid, which is colourless : a portion of the copper is soon dissolved by the nitric acid, and a fine blue solution of nitrate of copper is formed. Here a portion of the acid gives up oxygen to the metal, forming oxide of copper, which combines with the nitric acid. Red fumes of nitrous acid are given off.

By evaporation, this salt may be obtained in crystals.

3. Into a solution of sulphate of copper (blue vitriol) dip a clean piece of iron: the plate is covered with metallic copper. Here the copper is precipitated in consequence of the iron uniting with the acid to form sulphate of iron.

4. Add two drops of a strong solution of sulphate of copper to two glasses containing water: these solutions will be nearly colourless.

   I. To the first, add a drop of ammonia; light-blue oxide of copper falls: add ammonia now in excess; the precipitate is re-dissolved, and the solution assumes a fine deep-blue colour. This is a very delicate test of the presence of copper.

   II. To the second, add carbonate of potassa: light-blue carbonate of copper falls.

5. Place a few crystals of nitrate of copper on a piece of tinfoil; add a few drops of water to the crystals, and quickly fold up the tinfoil round them: a violent chemical action takes place, and the tinfoil inflames.

### LEAD.

31. The most common native form of lead is sulphuret of lead, or galena.

*Experiments.*

*1. Heat lead in* an iron spoon: it soon melts, and then *oxidates, by taking* oxygen from the air.

2. Arrange seven glasses, each containing a diluted solution of acetate of lead (sugar of lead).

i. To the first, add an alkali: the oxide of lead falls.
ii. To the second, add carbonate of potassa: the white carbonate of lead (white lead) falls.
iii. To the third, add sulphuric acid, or any sulphate: white sulphate of lead falls.
iv. To the fourth, add hydrochloric acid: white chloride of lead falls.
v. To the fifth, add a few drops of a solution of iodide of potassium: the beautiful yellow iodide of lead falls.
vi. To the sixth, add a few drops of the solution of chromate of potassa: yellow chromate of lead falls.
vii. To the seventh, add hydrosulphuret of ammonia: the black sulphuret of lead falls. See Exp. 4., Art. **60.**

3. Suspend a piece of zinc in a moderately strong solution of acetate of lead: the lead appears deposited on the zinc in an arborescent form, producing what is called the *lead tree.* Here the zinc takes the place of the lead, and the latter is precipitated.

## CHROME.

**32.** The most common salt of this metal, is bichromate of potassa.

### *Experiments.*

Arrange four glasses, each containing a diluted solution of bichromate of potassa.

1. To the first, add carbonate of potassa: it unites with the excess of acid, and yellow chromate of potassa appears.

2. To the second, add acetate of lead. See Exp. 2., *Art.* **31.**

3. To the third, add a few drops of the nitrate of mercury: the orange-coloured chromate of mercury falls.

4. To the fourth, add a few drops of the nitrate of silver (lunar caustic): brick-red chromate of silver falls.

## MERCURY.

**33.** This metal is sometimes found native in the metallic form, but it is most commonly combined with sulphur. This metal is a fluid.

### *Experiments.*

1. Heat a few grains of mercury in a test-tube over the spirit-lamp: the mercury rises in vapour, and condenses in globules in the cold part of the tube.

2. Heat a little sulphur, with about five times its weight of mercury, in a test-tube; close the mouth of the tube lightly with the forefinger: vermilion, or bisulphuret of mercury, is formed.

3. To a solution of chloride of mercury (corrosive sublimate) add a few drops of iodide of potassium: a red biniodide of mercury falls.

4. Heat some mercury with nitric acid; the mercury takes oxygen from a portion of the acid, and combines with the other portion; and a solution of nitrate of mercury is formed.

## ZINC.

**34.** This metal is now much used for making water-pipes and spouts.

### *Experiments.*

1. Take the solution of sulphate of zinc obtained by Exp. 1., Art. **14.**; evaporate a portion of the water off; set *the liquid aside to* cool: prismatic crystals of sulphate of *zinc fall.*

2. To a solution of sulphate of zinc add a few drops of ammonia (or potassa): white oxide of zinc falls. Add ammonia in excess: the precipitate is completely re-dissolved.

3. To a solution of zinc add a few drops of the carbonate of ammonia: carbonate of zinc falls, which is re-dissolved by an excess of the precipitant. These two experiments form the tests* for the presence of zinc.

## SILVER.

**35.** Silver is distinguished by its brilliant lustre and fine white colour.

### *Experiments.*

1. To a few small pieces of silver add diluted nitric acid; apply heat until the acid ceases to give off fumes: a solution of nitrate of silver is obtained; as the solution cools, crystals are deposited.

2. To a solution of nitrate of silver add potassa: an ash-grey powder of oxide of silver falls.

3. To a very diluted solution of nitrate of silver add hydrochloric acid: chloride of silver falls in the form of a white, curdy substance, which soon becomes black upon exposure to the light.

4. Write upon linen with a solution of nitrate of silver; and, when the writing is dry, wash it with a solution of potassa: the writing soon becomes permanently black, owing to the formation of oxide of silver.

## GOLD.

**36.** This metal is not affected by exposure to the air, and ordinary acids produce no action upon it.

### *Experiments.*

1. Put five or six gold leaves into a test tube; pour upon

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* For a complete system of testing, the student may consult "*Thompson's School Chemistry*," or "Bowman's Chemistry."

them a few drops of a mixture of nitric and hydrochloric acids; apply the flame of a spirit-lamp: the gold leaves are dissolved. Continue to apply a gentle heat, so as to expel any excess of acid: terchloride of gold remains. In this process, chlorine is set free from the hydrochloric acid, and combines with the gold.

2. Cover a slip of glass with a few drops of the terchloride of gold; apply the flame of a spirit-lamp: the chlorine is expelled, and gold is left upon the glass.

3. Put a drop of chloride of mercury on a gold ring; with the point of a penknife touch the gold through the drop: a permanently white spot of an amalgam of gold is produced.

### PLATINUM.

**37.** This metal is much used for making different kinds of chemical apparatus, on account of it being very infusible, and scarcely at all acted upon by ordinary chemical agents.

### *Experiments.*

1. Mix nitric acid with an equal bulk of hydrochloric acid; add the mixture to a few small pieces of platinum wire in a florence flask; digest, that is, keep the liquid at a slow boiling heat, until the acid is neutralised: a solution of bichloride of platinum is formed.

To obtain it perfectly free from acid, evaporate cautiously to dryness, and dissolve the residue in water.

2. Add a drop of the solution of bichloride of platinum to a glass of water; into this solution let fall a drop of iodide of potassium: a deep port-wine-coloured compound is immediately produced. The delicacy of this test is truly remarkable.

3. To the solution of bichloride of platinum, add a solution of hydrochlorate of ammonia: a yellow precipitate is formed, *a compound* of this salt and platinum.

*Decant off the liquid* and dry the precipitate; put it into the bowl of a tobacco-pipe, and bring it to a good red heat in the fire : metallic platinum, in a spongy state, is left, the other substances having been expelled by the heat.

4. Hold the spongy platinum before a stream of hydrogen gas: the metal soon becomes red hot, and the gas is ignited.

# CHAP. IV.

## DOCTRINE OF EQUIVALENTS. CHEMICAL NOMENCLATURE, SYMBOLS, ETC.

**38.** WHEN bodies combine with each other, it is always in certain fixed or definite proportions, that is, the same compound substance always contains the same elements combined in a constant proportion: thus water, whatever may be its quantity, or however generated, consists of 8 parts of oxygen to 1 part by weight of hydrogen: thus 1 part of hydrogen combines with 16 parts by weight of sulphur, to form sulphuretted hydrogen: thus 1 part of hydrogen combines with 6 parts by weight of carbon, to form carburetted hydrogen (olefiant gas). The numbers representing the proportional weights in which bodies combine, are called their *chemical equivalents.*

Taking 1 as the combining equivalent of hydrogen, 8 will be the combining equivalent of oxygen, 16 that of sulphur, and 6 that of carbon. Moreover, while 8 and 6 represent the proportional numbers in which oxygen and carbon respectively combine with hydrogen, these numbers also represent the proportion in which oxygen and carbon combine with each other or with any other substances: thus 8 parts of oxygen combine with 6 parts by weight of carbon, to form carbonic oxide. But this is not all: when the same bodies combine in more than one proportion, the proportional numbers representing each successive compound are multiples (or it may be submultiples) of those in the first compound. This law is exhibited in the following examples:

### *Compounds of Carbon and Oxygen.*

| | Proportion of Carbon. | | Proportion of Oxygen. | | |
|---|---|---|---|---|---|
| Carbonic oxide - - - - | 6 | + | 8 | = | 14 |
| Carbonic acid - - - - | 6 | + | 16 | = | 22 |

### *Compounds of Nitrogen and Oxygen.*

| | Proportion of Nitrogen. | | Proportion of Oxygen. | | |
|---|---|---|---|---|---|
| Protoxide of nitrogen - - | 14 | + | 8 | = | 22 |
| Binoxide of nitrogen - - | 14 | + | 16 | = | 30 |
| Hyponitrous acid - - - | 14 | + | 24 | = | 38 |
| Nitrous acid - - - - | 14 | + | 32 | = | 46 |
| Nitric acid - - - - - | 14 | + | 40 | = | 54 |

The equivalent of a compound body is the sum of the equivalents of its elements: thus the equivalent of carbonic oxide is 14, this number being the sum of 6 and 8: thus the equivalent of nitric acid is 54, this number being the sum of 14 and 40.

**39.** The following table contains a list of the names of the elementary substances, so far as they are at present known, with their symbols and combining equivalents. Those substances printed in Italics are rare, and of comparatively little importance.

*Table of Equivalents and Symbols of Simple Substances.*

| Sym. | Name. | Equiv. | Sym. | Name. | Equiv. |
|---|---|---|---|---|---|
| H | Hydrogen | 1 | Mn | Manganese | 28 |
| O | Oxygen | 8 | Ni | Nickel | 30 |
| N | Nitrogen | 14 | Ba | Barium | 68 |
| Cl | Chlorine | 36 | Sr | Strontium | 44 |
| C | Carbon | 6 | As | Arsenic | 76 |
| I | Iodine | 126 | Sb | Antimony | 128 |
| S | Sulphur | 16 | Bi | Bismuth | 108 |
| P | Phosphorus | 16 | Te | *Tellurium* | 64 |
| F | Fluorine | 18 | V | *Vanadium* | 68 |
| Br | Bromine | 78 | U | *Uranium* | 60 |
| B | Boron | 10 | Mo | *Molybdenum* | 48 |
| Se | *Selenium* | 40 | Tn | *Tungsten* | 94 |
|  | *Metals:* |  | Ti | *Titanium* | 24 |
|  |  |  | Cm | *Columbium* | 184 |
| K | Potassium | 40 | Nr | *Niobium* | ? |
| Na | Sodium | 24 | Pe | *Pelopium* | ? |
| L | *Lithium* | 6 | No | *Norium* | ? |
| Ca | Calcium | 20 | G | *Glucinum* | 26 |
| Mg | Magnesium | 12 | Zr | *Zirconium* | 34 |
| Si | Silicon | 8 | Th | *Thorium* | 60 |
| Al | Aluminum | 14 | D | *Didymium* | ? |
| Fe | Iron | 28 | Ln | *Lantanum* | 48 |
| Cu | Copper | 32 | Ce | *Cerium* | 46 |
| Pb | Lead | 104 | Y | *Yttrium* | 32 |
| Zn | Zinc | 33 | Tb | *Terbium* | ? |
| Cr | Chrome | 28 | E | *Erbium* | ? |
| Hg | Mercury | 100 | Cd | *Cadmium* | 56 |
| Ag | Silver | 108 | Pd | *Palladium* | 54 |
| Au | Gold | 100 | R | *Rhodium* | 52 |
| Pl | Platinum | 98 | Os | *Osmium* | 100 |
| Sn | Tin | 58 | Ir | *Iridium* | 98 |
| Co | Cobalt | 30 | Ru | *Ruthenium* | 52 |

The arrangement of the elementary substances, in this Table, is merely adopted to suit the order observed in the other portions of this work.

**40.** The first letter or letters of the Latin name of a simple substance, is taken as its symbol; and the symbol of any substance always represents its combining equivalent. Thus O stands for one equivalent of oxygen; 2 O or $O_2$ stands for two equivalents of oxygen, and so on. Compounds are expressed by the equivalents of simple substances which enter into their composition: thus, sulphuric acid is composed of one equivalent of sulphur and 3 equivalents of oxygen;

the symbol of sulphuric acid, therefore, is $S + O_3$, or more simply $SO_3$, and the combining equivalent $= 16 + 3 \times 8 = 40$.

The sign of equality ($=$) is used to express an identity of *composition*, but not always an identity in the *form* of the arrangement of the elements.

The names given to compound substances are such as to indicate their elementary composition.

Compounds containing oxygen are called *acids* or *oxides*, according as they do or do not possess acidity. Thus an oxide of iron contains oxygen and iron. The termination *ic* is placed to the name of a substance, when it becomes an acid: thus we have sulphur*ic* acid, which is a compound of sulphur and oxygen. When the substance forms two acids, that which contains the smallest portion of oxygen terminates in *ous*: thus we have sulphur*ous* acid. The termination *uret* also indicates the combination of a variety of substances: thus we have sulph*uret* of iron, which expresses a compound of sulphur and iron. Degrees of oxidation are sometimes expressed by Greek or Latin prefixes: thus *prot*oxide expresses the first degree of oxidation, *bin*oxide the second, *ter*oxide the third, and so on. The highest degree of oxidation is usually expressed by the term *per*oxide. When an acid, whose name ends with an *ic*, forms a salt, its name terminates with an *ate*: thus nitr*ic* acid forms a nitr*ate*; while a sulphur*ous* acid forms a sulph*ite*; and so on to other cases.

### *Exercises on the Use of Chemical Formulæ.*

**41.** One of the greatest advantages of chemical formulæ is, that they enable us to represent chemical combinations and changes with such clearness and precision.

1. 1 eq.* water = 1 eq. hydrogen + 1 eq. oxygen
$= H + O$ or $HO$,
$= 1 + 8 = 9$.

2. 1 eq. carbonic acid = 1 eq. carbon + 2 eq. oxygen
$= C + O_2$, or $CO_2$,
$= 6 + 2 \times 8 = 22$.

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* *Eq.* is used as an abbreviation of the word equivalent.

3. 1 eq. nitric acid = 1 eq. nitrogen + 5 eq. oxygen
$= N + O_5$, or $NO_5$,
$= 14 + 5 \times 8 = 54$.

4. 1 eq. potassa = 1 eq. potassium + 1 eq. oxygen
$= K + O$, or $KO$,
$= 40 + 8 = 48$.

5. 1 eq. carbonate of potassa = 1 eq. potassa + 1 eq. carbonic acid
$= KO + CO_2$, or $KO\,CO_2$,
$= 48 + 22 = 70$.

6. 1 eq. ammonia = 1 eq. nitrogen + 3 eq. hydrogen
$= N + H_3$, or $NH_3$,
$= 14 + 3 \times 1 = 17$.

7. 1 eq. hydrochloric acid = 1 eq. hydrogen + 1 eq. chlorine
$= H + Cl$, or $HCl$,
$= 1 + 36 = 37$.

8. 1 eq. hydrochlorate of ammonia $= NH_3 + HCl$
$= 17 + 37 = 54$.

9. 1 eq. bichloride of platinum $= Pl + 2\,Cl$, or $PlCl_2$
$= 98 + 2 \times 36 = 170$.

10. 1 eq. lime = 1 eq. calcium + 1 eq. oxygen
$= Ca + O$, or $CaO$,
$= 20 + 8 = 28$.

11. 1 eq. carbonate of lime $= CaO + CO_2$, or $CaO\,CO_2$
$= 28 + 22 = 50$.

12. The action in Exp. 3., Art. 12. is as follows:—

1 eq. carbonate of potassa + 1 eq. lime
$= KO\,CO_2 + Ca\,O$,
$= KO + CaO\,CO_2$.

*Here KO, or potassa,* remains in solution, and $CaO\,CO_2$, *or carbonate of lime,* is precipitated.

13. The action in Exp. 1., Art. **14.** is as follows :—

1 eq. sulphuric acid + 1 eq. water + 1 eq. zinc

$$= SO_3 + HO + Zn,$$
$$= ZnO\ SO_3 + H.$$

Here $ZnO\ SO_3$, or sulphate of oxide of zinc, remains in solution, and the hydrogen is given off.

14. The action in Exp. 1., Art. **13.** is as follows :—

1 eq. hydrochloric acid + 1 eq. carbonate of lime

$$= HCl + CaO\ CO_2,$$
$$= CaCl + HO + CO_2.$$

Here $CaCl + HO$, or chloride of calcium with water, is formed, and $CO_2$, or carbonic acid, is given off.

15. The action in Exp. 1., Art. **26.** is as follows :—

1 eq. sulphate of magnesia + 1 eq. carbonate of potassa

$$= MgO\ SO_3 + KO\ CO_2,$$
$$= KO\ SO_3 + MgO\ CO_2.$$

Here $MgO\ CO_2$, or carbonate of magnesia, falls, and $KO\ SO_3$, or sulphate of potassa, remains in solution.

16. 1 eq. nitrate of copper, or nitrate of the oxide of copper,

$$= 1 \text{ eq. oxide of copper} + 1 \text{ eq. nitric acid}$$
$$= CuO + NO_5, \text{ or } CuO\ NO_5.$$

17. The action in Exp. 3., Art. **35.** is as follows :—

1 eq. nitrate of the oxide of silver + 1 eq. hydrochloric acid

$$= AgO\ NO_5 + HCl,$$
$$= NO_5 + HO + AgCl.$$

Here $NO_5$, or nitric acid with water, remain in solution, and $AgCl$, or chloride of silver, falls.

# CHAP. V.

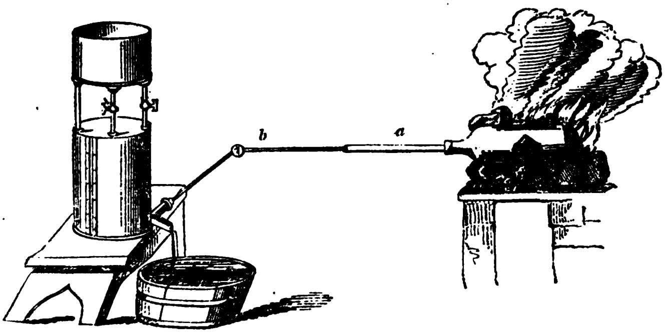
## EXPERIMENTS CONDUCTED ON A LARGER SCALE, OR WITH A MORE COMPLETE APPARATUS.

### OXYGEN — O.

**42.** *Preparation.* To obtain oxygen pure, the substance which supplies it is placed in a retort or tube, and exposed to heat; when gas is evolved it must be collected over water, either in the pneumatic trough or in a gas-holder. See pages 20. and 21.

**43.** *Oxygen obtained from black oxide of manganese.* This substance is used by itself when large quantities of the gas are required. The oxide is introduced into an iron bottle, to the mouth of which an iron tube, *a*, is adapted, and luted or plastered over with common pipe-clay, made into paste with water. The extremity of this tube is luted to a flexible tube, *b*, the outer end of which is inserted into the water of a gas-holder. The bottle is placed upon a good fire. When the manganese attains a red heat, it gives off a portion of its oxygen, which rises within the gas-holder.

The chemical changes which take place in this process are exhibited in the following formulæ: —

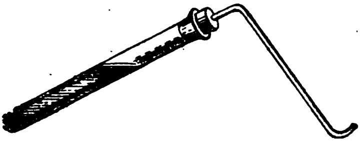


$$3 \text{ eq. binoxide of manganese}$$
$$= 2\,Mn\,O_2 = Mn_2\,O_4 = Mn_2\,O_3 + O.$$

Here, after the process is completed, $Mn_2\,O_3$, or sesquioxide of manganese, remains in the retort. The gas should stand for a short time over water, in order to absorb any carbonic acid gas which it may contain.

**44.** *Oxygen obtained from chlorate of potassa.* Mix about equal parts of chlorate of potassa and black oxide of manganese in a mortar; introduce the mixture into a small copper or green glass retort; apply the flame of a spirit-lamp, and receive the gas in the gas-holder, or the pneumatic trough.

If only a small quantity of the gas is wanted, the mixture may be introduced into a large test tube, having a cork perforated by a bent exit tube, as in the annexed cut.



The decomposition is represented by the following formulæ:—

$$1 \text{ eq. chlorate of potassa}$$
$$= 1 \text{ eq. potassa} + 1 \text{ eq. chloric acid}$$
$$= KO + Cl\,O_5 = KCl + O_6.$$

Here the heat resolves the chlorate of potassa into $KCl$, or chloride of potassium, and $O_6$, or 6 eq. of oxygen. The manganese in the mixture merely aids in keeping a steady heat.

### *Experiments with Oxygen.*

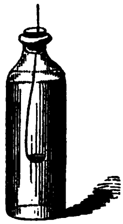
1. Introduce a lighted taper into a bottle of this gas: the flame is increased in size and brilliancy. Introduce a candle with a wick red: it bursts into flame.

2. Put some pounded charcoal on a cup attached to a wire passing through a cork; heat the charcoal, over a spirit-lamp, to redness;

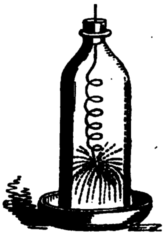
plunge it into the gas: the charcoal glows with great brightness, and bursts into flame. Here the product of combustion is carbonic acid gas.

3. Burn phosphorus in the same manner: it burns with great splendour.

4. Burn sulphur in the same manner: it burns with a beautiful blue flame.

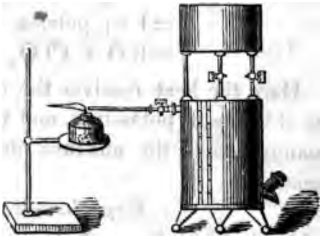


5. Roll a piece of fine steel wire in a spiral form round a glass tube; fix one extremity of the wire in a cork, and to the other extremity attach a piece of cotton wick dipped in melted sulphur; ignite the wick, and plunge it into a bottle of oxygen: the wire takes fire, and burns with beautiful scintillations. The product of combustion in this case is oxide of iron. To prevent the bottle from breaking, the bottom should be covered with sand.



6. Introduce some dark-coloured venous blood into a bottle of oxygen: the blood, upon being shaken, soon acquires the florid colour of arterial blood.

7. Project the oxygen from a gas-holder on the flame of a spirit-lamp: great heat is produced. Hold a small piece of chalk or lime before the flame: the light of the lime is brilliantly white and intense. Burn a piece of watch-spring in the flame; &c.



8. Take a large piece of charcoal, and make a small hole in it; hold this part of the charcoal over a lamp until it becomes red hot; drop a small cast-iron nail into the hole; hold the heated charcoal before a stream of oxygen, (issuing from a jet with its orifice turned downwards): the charcoal burns rapidly; the nail becomes white hot, then fuses, and

finally burns, giving off a brilliant shower of ignited sparks of the metal. This is one of the most beautiful experiments in the whole range of chemistry.

Various other metals may be ignited in the same manner.

*The common mouth blow-pipe.* This consists of a brass tube, having a very small orifice or jet at one end, for projecting a small constant stream of air upon the flame. In the flame of a common candle, *b* is a hollow cone containing combustible gases in excess; this is surrounded by a sheet of flame *a*, where the combustible material is in contact with the oxygen of the air. When we blow through this flame, by means of the blow-pipe, the circumstances are completely changed: in the second figure, contains a powerful flame, having combustible gases in excess; this portion is called the DEOXIDISING OR REDUCING FLAME, for it deprives substances of their oxygen; *a*, in the second figure, is a flame where the oxygen preponderates; this portion is called the OXIDISING FLAME, for it communicates oxygen to the substance heated in it.

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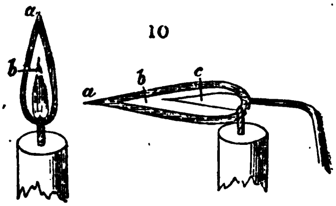


When a metal is to be brought to the state of an oxide, it is placed in the oxidising flame *a*; and when an oxide is to be *reduced* to the metallic state, it is placed in the deoxidising or reducing flame *b*. The most powerful heat is produced at the apex of the cone *c*.

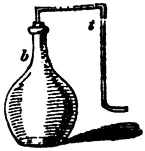
In using the mouth blow-pipe, the student must endeavour to acquire the power of keeping up a constant and steady blast, by forming his mouth into a bag of air, while at the same time he breathes through his nostrils. The manner of doing this is difficult to explain: by repeated trials, however, *he will see that* it is possible to do so.

*Experiment.* Place one or two grains of oxide of lead (litharge) on a piece of charcoal, and hold the substance in the reducing flame *b;* the metallic lead is produced in the form of a brilliant globule; bring the globule to the oxidising flame *a;* the metal is oxidised, and presents a dull appearance. Various other metals may be treated in the same manner.

The peculiar action of the flame of the blow-pipe constitutes a most interesting and useful department of experimental chemistry. On this subject the student may consult "Griffin's Chemical Recreations."

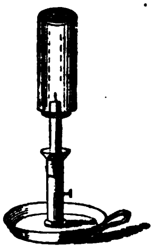
### HYDROGEN.

**45.** *Preparation.* This gas is most conveniently prepared from zinc and diluted sulphuric acid. Put some zinc cuttings, sulphuric acid, and about five times the quantity of water, into a retort *r*, (see cut, page 20., Art. **18.**) or into a bottle *b*, with the bent tube *t;* great heat is produced by the mixture of the acid and water, and the gas is copiously evolved, which may be received over water in the pneumatic trough or in the gas-holder. See Exercise 13, Art. **41.**



### *Experiments with Hydrogen.*

1. Invert a jar of hydrogen over a candle; the flame of the candle is extinguished, but the gas burns at the mouth of the vessel. In this way the gas takes some time before it is burnt away.

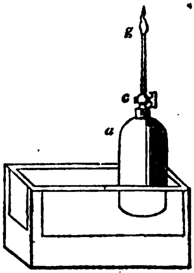


2. Ignite a jar or bottle of hydrogen, having the mouth of the vessel uppermost; in this case the gas burns much more quickly away, in consequence of its great lightness as compared with the air.

3. Introduce the gas into a jar *a*, having a gas-burner *g*, and stop-cock *c*; open the cock, and at the same time depress the jar in the water; ignite the gas as it issues from the small orifice *g*: the gas burns with a pale yellow flame, which gives off a great deal of heat.

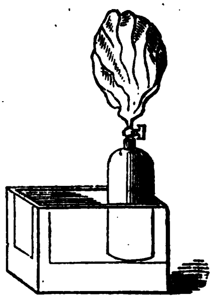
Hold a dry tumbler glass over the flame: water is deposited.

Repeat Exp. 2., Art. **14.**.

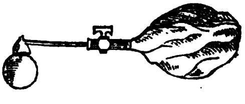


4. Mix in a strong bottle 1 measure of hydrogen with 2½ or 3 measures of common air; apply the flame of a candle to the mouth of the bottle: the mixture detonates with a considerable report.

5. Fill a bladder with this gas from a capped receiver at the pneumatic trough, as exhibited in the annexed cut, or from the gas-holder; adjust a common tobacco-pipe to the stop-cock, and blow soap bubbles by giving a gentle pressure to the bladder: these soap bubbles, being filled with hydrogen, are lighter than the air, and they ascend in the atmosphere like little balloons. Bring the flame of a candle in contact with one of these hydrogen bubbles: it explodes.



6. Fill a small balloon with hydrogen, or with common street gas, and load it with a light paper car, so as to keep it suspended in the air.



7. Throw a stream of hydrogen on spongy platinum. (See Exp. 3., Art. **37.**) To ensure the success of the experiment, the platinum should be previously heated to redness before the spirit-lamp.

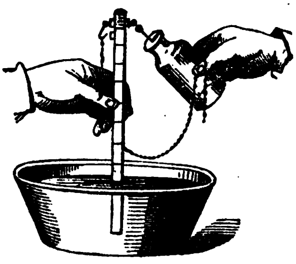
8. Mix over the pneumatic trough a portion of oxygen with twice its volume of hydrogen; fill a common soda water

bottle with the mixed gases; apply the flame of a taper: the gases detonate with a loud report.

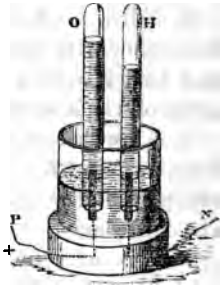
### *Composition of Water.*

**46.** It has already been explained that water is composed of 8 parts by weight of oxygen and 1 part of hydrogen. Now oxygen is exactly 16 times heavier than hydrogen; hence it follows that there must be double the quantity by volume of hydrogen to form water. The composition of water may be determined in two ways: first, by *synthesis*, or by bringing the elements together; second, by *analysis*, or by separating the elements from each other.

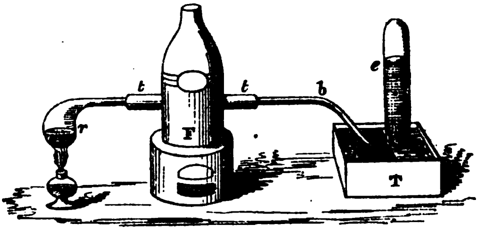
*Synthesis.* Introduce the mixed gases, 2 volumes or measures of hydrogen and 1 volume or measure of oxygen, into a strong graduated tube (Volta's *Eudiometer*), having two wires nearly meeting each other within the tube at the top; pass an electric spark through the mixed gases by means of a charged Leyden-jar, as shown in the annexed cut: the gases combine with ignition, water is formed, and a complete vacuum is produced, which is filled up by the ascent of the water in the trough.



*Analysis.* Two equal tubes, O and H, filled with water are inverted over the two poles of a galvanic battery; when the battery is put in action the water is resolved into the two gases; the oxygen rises in the tube O placed over the positive pole, and the hydrogen into the tube H placed over the negative pole. As the analysis proceeds, it will be seen that the volume of the hydrogen is always double that of the oxygen.

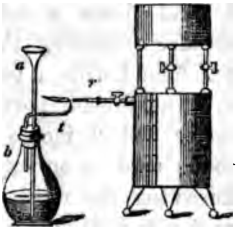


**47.** Water is also decomposed by passing a current of steam through an iron tube partially filled with iron-filings, and kept at a red heat by a furnace. In this cut, *r* represents the retort in which the water is being boiled; *tt* the red-hot tube passing through the furnace F: the bent pipe *b* conveys the hydrogen gas into a jar *e* standing on the shelf of a pneumatic trough T. In this interesting experiment the steam passing over the heated iron is decomposed; the iron, taking up the oxygen, becomes an oxide of iron, and the hydrogen is disengaged.



### *Ignition of the Mixed Gases. Oxyhydrogen Blow-pipe.*

**48.** The simplest manner of showing the intense heat generated by the ignition of mixed gases is as follows. The hydrogen is formed in the bottle *b*, the cork of which is perforated by two tubes; *a* is a funnel-shaped tube, for the purpose of supplying sulphuric acid as it is required; *t* is a bent tube conveying the hydrogen for ignition*; *r* is the tube with a stop-cock and jet, conveying a stream of oxygen from a gas-holder on the hydrogen flame. The



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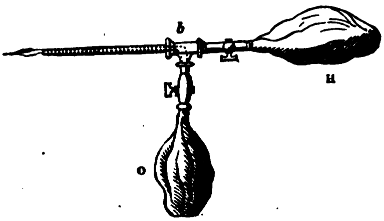
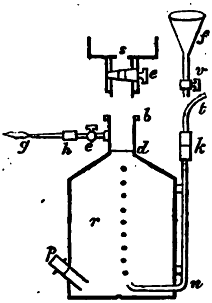
* This is an excellent arrangement for making hydrogen, as well as sulphuretted hydrogen, when large quantities are required.

various experiments described in Art. **44.** may be tried with this flame.

**49.** *Daniel's Blow-pipe.* In this apparatus a common tube *b* receives the two gases contained in the bladders H and O, provided with stop-cocks. The hydrogen is first ignited, and then the pressure upon the bladder containing the oxygen is regulated so as to produce the maximum heating effect on the flame.



**50.** The following economical apparatus, answering the double purpose of a gas-holder and an oxyhydrogen blow-pipe, has been successfully used by the author of this work. In the annexed cut, *r* represents the gas receiver; *s* a shelf which screws on at *b*; *e* and *c* stop-cocks, as in the ordinary gas-holder (see p. 21.); *h g* a jet filled with wire gauze at the thick part *h*; *p* an aperture for receiving the beak of a retort; *n k* a bent pipe passing into the interior of the receiver *r*; *k t* a flexible tube, which screws on at *k*, and forms a connection with a bladder containing the mixed gases; *f* a funnel with a tube and stop-cock for screwing on at *k*. The tubular portion *d b* is about ¾ inch internal diameter and 2 inches in length. When the apparatus is to be used as an oxyhydrogen blow-pipe, water is introduced into the receiver, so as to stand at the level *d*; the orifice at *b* is closed by means of a cork, and the bladder containing the mixed gases is screwed on at *k*; the safety jet *h g* is screwed on the stop-cock *e*; upon pressure *being applied to* the bladder, the mixed gases rise through



the water, and, filling the space *d b*, pass out in a strong stream through the jet *g*, and are there ignited. This arrangement is perfectly safe, for in the event of the flame passing along the safety tube *h*, we can only have an explosion of the gases contained in the small chamber *d b*, the only effect of which would be to blow out the cork in the orifice *b*, as the large body of water in *r* most effectually cuts off all communication with the gases in the bladder. When the apparatus is to be used as a gas-holder, the shelf *s* is screwed on at *b*, the funnel *f* at *k*, and gases are received and transmitted in the same manner as in the ordinary gas-holder.

### *Analysis of the Atmospheric Air by the Detonation of Hydrogen in Volta's Eudiometer.*

**51.** Mix over the pneumatic trough 2 volumes of atmospheric air and 1 volume of hydrogen; introduce a small portion of this mixture into the eudiometer tube (Art. **46.**) so as to occupy 15 divisions of the tube; detonate by the electric spark: after detonation the gas only occupies 9 divisions of the tube; that is, 6 parts have disappeared, in consequence of all the oxygen having combined with a portion of the hydrogen to form water. Now the gaseous mixture in the tube contained 10 parts of air and 5 of hydrogen; and since water is composed of 1 volume of oxygen and 2 volumes of hydrogen, one-third of the diminution must give the quantity of oxygen in the 10 volumes of air originally in the tube; that is, 2 volumes of oxygen have disappeared; but 2 is one-fifth of 10; therefore one-fifth of atmospheric air is oxygen, and the remaining four-fifths are nitrogen: hence in 100 volumes of air, 20 are oxygen and 80 are nitrogen.

### NITROGEN AND ITS COMPOUNDS WITH OXYGEN.

**52.** For the preparation and properties of nitrogen, see Art. 15., and Exps. 4. and 5.

### *Protoxide of Nitrogen*—$NO$.

This gaseous compound is familiarly known by the name of the *laughing-gas*, from the ludicrous effect which it has upon persons who respire it. This gas is not inflammable, but it supports combustion with greater brilliancy than common air.

*Preparation.*—Introduce some crystals of nitrate of ammonia * into a large retort; apply the heat of an Argand lamp having a copper flue, to give steadiness to the flame: at a temperature of 400° the salt fuses, and then gives off the gas in great abundance, which may be received in the gas-holder filled with *warm* water, as cold water largely absorbs the gas. It should stand for two or three hours over a little water, to absorb any fumes of nitrous acid that may be formed in the process. The whole of the salt is resolved by heat into this gas and water, as shown by the following symbols:—

$$\begin{aligned}&\text{1 eq. nitrate of ammonia}\\&=\text{1 eq. ammonia} + \text{1 eq. nitric acid}\\&=NH_3 + NO_5\\&=H_3 + O_3 + N_2 + O_2 = 3HO + 2NO.\end{aligned}$$

Hence it appears that 1 eq. of nitrate of ammonia yields 3 eq. of water and 2 eq. of the protoxide of nitrogen.

### *Experiments.*

1. Plunge a burning candle into a bottle of this gas: the flame is much increased in brilliancy in consequence of the large quantity of oxygen which the gas contains.

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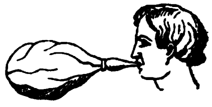
* To prepare this salt, add carbonate of ammonia in powder to nitric acid diluted with about three parts of water until effervescence ceases; evaporate the solution until a drop of the liquid let fall upon a cold plate becomes a solid mass. A little ammonia should be added towards the close of the process to render the salt perfectly alkaline.

2. Introduce a large splinter of wood having a glowing red spark into this gas: the flame is re-kindled, as in the case of oxygen gas.

3. Transfer this gas from the gas-holder into a damp bladder having a wide wooden mouth-piece; place the mouth-piece between the teeth of the person who is to inhale the gas; let him close his nostrils with his forefinger and thumb, and then let him breathe the gas in the bladder: various effects, more or less ludicrous, are produced upon persons inhaling the gas. All kinds of apparatus should be removed, for they are liable to be injured by the inhaler.



### *Binoxide of Nitrogen*—$NO_2$.

This compound is a colourless gas, similar in appearance to common air: it is sparingly absorbed by water.

*Preparation.*—Put some copper cuttings into a retort, pour nitric acid upon them, and then add about an equal quantity of water[*]: brisk effervescence takes place without the aid of heat, and the gas may be collected over water in the pneumatic trough.

The decomposition is represented by the following formulæ:—

$$\begin{aligned} &4 \text{ eq. nitric acid} + 3 \text{ eq. copper} \\ &= 4\,NO_5 + 3\,Cu \\ &= NO_2\,O_3 + 3\,NO_5 + 3\,Cu \\ &= NO_2 + 3\,(Cu\,O + NO_5) \end{aligned}$$

= binoxide of nitrogen + 3 nitrate of the oxide of copper.

### *Experiments.*

1. Transfer a bottle of this gas over the pneumatic trough into a similar bottle nearly filled with common air; red fumes of nitrous acid ($NO_4$) are instantly formed, which are soon absorbed by the water. This constitutes a charac-

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[*] The diluted acid should have a specific gravity of 1·2.

teristic property of the binoxide of nitrogen, and it is used in this way to detect the presence of free oxygen.

2. Plunge a piece of burning phosphorus into a bottle of this gas: the phosphorus continues to burn.

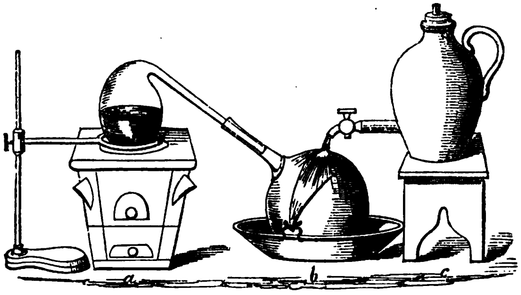
3. Burn a mixture of this gas and hydrogen (see cut to Exp. 3., Art. **45.**): the mixed gases burn with a green-coloured flame.

4. Transfer a bottle of binoxide of nitrogen to a cup containing a solution of sulphate of iron: the solution becomes black.

### *Nitric Acid*—$NO_5$.

For the leading properties of this acid, see Art. **17.**

*Preparation.* Mix equal weights of nitrate of potassa (nitre) and oil of vitriol of commerce in a retort; heat the retort over a chauffer *a*, containing heated charcoal (a sand bath or an Argand lamp would answer the purpose equally as well): nitric acid distils over, and is condensed in the liquid form in the receiver *b*, kept cool by a stream of water proceeding from a jar *c*. The stream of water may be conveniently supplied from a funnel having its tube partially closed by a piece of rag.



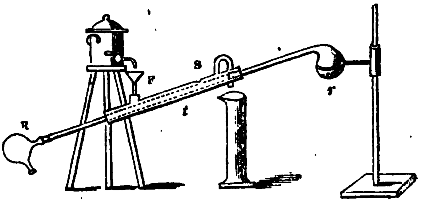
The decomposition is as follows:—

2 eq. sulphuric acid + water + 1 eq. nitrate of potassa

$$\Rightarrow 2\,SO_3 + 2\,HO + KONO_5$$
$$= KO\,2SO_3 + HO + NO_5 + HO$$

= *bisulphate of* potassa and water + nitric acid and water.

DISTILLATIONS of any kind are conveniently effected by means of LIEBIG'S CONDENSING TUBE.



The liquid to be distilled is placed in the retort *r*, to which a sufficient heat is applied to boil the liquid: the vapour, as it passes along the tubes, is condensed by the cold kept up in the condensing tube s*t*F, and the liquid drops into the receiver R. The construction of this condensing tube is exceedingly ingenious: *t* is a wide tin tube; F a funnel passing into it for the purpose of supplying cold water; S a syphon for carrying off the hot water; a glass tube passing through this tin tube is connected with the beak of the retort and the receiver R; this glass tube passes through perforated corks inserted at each end of the tin tube *t*. Now this glass tube is continually surrounded by cold water; for while cold water is being supplied by the funnel F, the water, as it becomes heated, rises within the tin tube, and is carried off by the syphon S.

*Experiment.* Heat gently some oil of turpentine in a porcelain basin; pour suddenly upon it a mixture of one part of sulphuric acid and two parts of nitric acid: combustion takes place, with the evolution of a dense smoke. In order to avoid accident, the mixed acid should be poured from a bottle tied to the end of a stick.

## CARBON, SULPHUR, AND PHOSPHORUS, THEIR COMPOUNDS WITH OXYGEN AND HYDROGEN.

### *Carbonic Oxide*—$CO$.

**53.** This is a colourless gas; it is the gas that burns with a blue flame at the top of a coke or charcoal fire.

*Preparation.* Mix pounded oxalic acid with sulphuric acid in a retort, and apply heat: carbonic oxide and carbonic acid gases are given off, which may be received over the pneumatic trough. By allowing the gases to stand over water for a few hours, or by agitating them with lime water, the carbonic acid gas is absorbed, and the carbonic oxide is left pure. Oxalic acid may be regarded as a compound of carbonic oxide and carbonic acid with water; thus:—

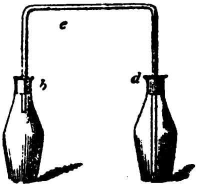
1 eq. oxalic acid $= C_2O_3 +$ water $= CO + CO_2 +$ water.

Now the sulphuric acid combines with the water and sets the two gases free.

*Experiment.* Plunge a lighted taper into a bottle of this gas: the taper is extinguished, but the gas burns at the mouth of the bottle with a beautiful blue flame: thus *carbonic oxide is inflammable, but it does not support combustion.*

### *Carbonic Acid*—$CO_2$.

**54.** *Preparation.* Carbonic acid gas, being more than $1\frac{1}{2}$ times heavier than common air, may be prepared sufficiently pure by the following process. The gas is generated in the bottle *b* (see Exp. 1., Art. **13.**); a bent tube *bed* passes through a cork *b*, and descends to the bottom of the open bottle *d*: as the gas enters the bottle *d*, the common air is displaced.[*] A little experience will readily enable the experimenter to ascertain when the bottle is filled with the gas.



When this gas is received over the pneumatic trough, the water should be warm; for carbonic acid gas is largely absorbed by cold water.

### *Experiments.*

1. Invert a jar or bottle of the gas over a burning candle:

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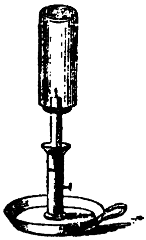
[*] Gases which are lighter than the air, such as ammoniacal gas, may be received in bottles with their mouths inverted.

the gas, by its gravity, falls upon the candle, and extinguishes the flame.



2. Place a burning candle in an open jar; take a bottle of carbonic acid gas, and pour it into the jar: the flame is extinguished. This shows that carbonic acid gas is much heavier than common air. 3. Pour some lime-water into a bottle containing this gas: carbonate of lime is formed: shake the liquid, and it becomes clear, in consequence of the carbonate of lime being soluble in an excess of carbonic acid. In this way lime is dissolved in spring-water.

4. Add a little water to a bottle of the gas; shake the bottle: the water takes up the gas, and acquires decided acid properties; add a little solution of litmus: the blue is changed to red.

### *Carburetted Hydrogen*—$CH_2$.

**55.** This gas is formed in marshes and stagnant pools; it is but little more than half the weight of common air; it is highly inflammable, and forms the *fire-damp* of the miners. When coal is heated to redness, it is resolved into tarry matter, and certain gaseous compounds of carbon and hydrogen, containing about 70 per cent. of carburetted hydrogen.

### *Experiments.*

1. Invert a bottle filled with water in a stagnant pool; insert a funnel into the bottle to catch the gas; stir up the bottom of the pool with a stick: bubbles of carburetted hydrogen gas rise, which are easily received through the funnel. Ignite the gas thus obtained: it burns with a yellow flame.

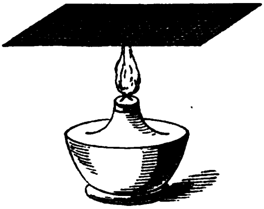
2. Mix 1 measure of this gas with 7 or 8 of common air, in a bottle; apply the flame of a candle: the gas explodes with some violence. Mix 1 measure of the gas with 3 or 4 measures of air, and ignite the gases: they burn without explosion.

3. Put some pounded coal into a test-tube, fitted with a cork and the stem of a tobacco-pipe; apply the flame of a spirit-lamp: gas is disengaged, which may be inflamed as it issues from the small orifice of the pipe.

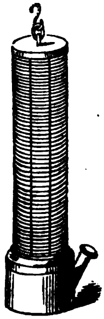
4. The flame of a candle is produced by the ignition of carburetted hydrogen gases. Bring one extremity of a tube, about $\frac{3}{8}$ths of an inch in diameter, into the centre of the flame of a candle: the gases rise up the tube, and may be ignited as they escape at the upper end. This experiment also shows that flame is hollow.

**56.** *The Davy lamp.* Carburetted hydrogen occurs in coal-pits from the decomposition of the coal, where it sometimes explodes by coming it contact with flame; and thus melancholy accidents take place. The Davy lamp is designed to prevent these explosions.

*Experiment.* Take a piece of fine wire gauze, and hold it across the flame of a candle: the flame does not pass through the gauze. Blow out the flame, and ignite the smoke as it rises through the gauze: the flame does not descend below the gauze.



This experiment exhibits the principle upon which the Davy lamp is constructed: the metal, being a high conductor of heat, cools down the temperature of the inflammable matter in contact with it, and thereby extinguishes the flame on the side opposite to the burning body. The Davy lamp simply consists of a lamp surrounded by wire gauze to prevent flame extending from the interior of the lamp to the adjacent atmosphere.



### *Olefiant Gas, or Heavy carburetted Hydrogen*—$C_4 H_4$.

**57.** This gas, owing to its illuminating power, is the most valuable constituent of street gas. It contains a larger quantity of carbon than the light carburetted hydrogen. Coal gas, when well prepared, contains about 20 per cent. of olefiant gas.

*Preparation.* Mix one part of alcohol with 5 or 6 parts of sulphuric acid in a retort; apply the heat of an Argand lamp: the gas comes over in great abundance, which may be received, over water, in the pneumatic trough.

### *Experiments.*

1. Plunge a lighted candle into a bottle of this gas: the flame of the candle is extinguished; but the gas burns, at the mouth of the bottle, with a fine, brilliant flame.

2. Burn this gas in a capped receiver. (See cut to Exp. 3., Art. **45.**)

3. Mix 3 volumes of oxygen with 1 volume of olefiant gas in a strong common soda-water bottle; ignite the mixed gases: a violent explosion takes place, carbonic acid and water being formed: thus we have

olefiant gas and oxygen

$$= C_2 H_2 + O_6 = 2CO_2 + 2HO.$$

1. Mix 2 measures of chlorine with 1 measure of olefiant gas in a bottle; introduce a lighted candle: the gases burn with a red flame, with a copious deposition of lamp black thereby showing that olefiant gas contains carbon.

### *Sulphurous Acid*—$S O_2$.

**58.** This acid may be procured in a pure state by boiling in a retort sulphuric acid with copper cuttings: the gas may be received by displacement, as in Art. **54.** The action is represented by the following symbols:—

2 eq. sulphuric acid + 1 eq. copper

$= 2\,SO_3 \quad + Cu$

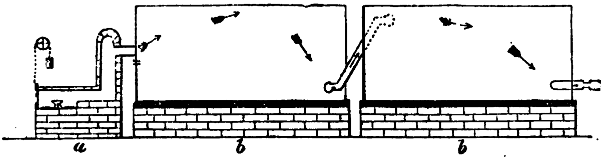
$= SO_2 \quad + CuO\,SO_3$

= sulphurous acid + sulphate of oxide of copper.

By passing a current of the gas through water, a solution of sulphurous acid is obtained. It unites with bases, forming sulphites. The gas is used in bleaching woollens.

## *Sulphuric Acid*—$SO_3$.

**59.** This valuable acid is made by the manufacturer on a large scale, by burning sulphur in a furnace, where nitric acid is, at the same time, formed by the decomposition of nitrate of soda by means of sulphuric acid: the sulphurous and nitric acids pass into a succession of leaden chambers containing a portion of water, to dissolve the sulphuric acid as it is being formed by the nitric acid giving up a portion of its oxygen. In the annexed cut *a* represents the furnace in which the sulphurous and nitric acids are formed; *bb* the leaden chambers containing some water. The sulphur is spread over the bottom of the furnace, and the nitre is placed in the cup, shown in the cut. The second chamber communicates with a high chimney, for creating a draft, and also for carrying off the surplus vapours.



## *Sulphuretted Hydrogen, or Hydrosulphuric Acid*—H S.

**60.** *Preparation.* Heat sulphuret of antimony in a retort, with 4 or 5 times its weight of hydrochloric acid, and collect the gas over warm water in the pneumatic trough (or by displacement, as in Art. **54.**). As the bottles are filled with the gas, they should be speedily removed and closed.

The action is represented in the following symbols:—

1 eq. sesquisulphuret of antimony + 3 eq. hydrochloric acid

$$= Sb_2\, S_3 + 3\, H\, Cl$$
$$= 3\, H\, S + Sb_2\, Cl_3$$

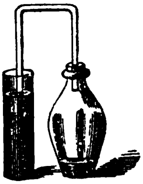
= 3 eq. sulphuretted hydrogen + 1 eq. sesquichloride of antimony.

### *Experiments.*

1. Invert a jar of this gas; apply a lighted match: the gas burns with a pale blue flame with the deposition of sulphur.

2. Pour a few drops of strong nitric acid into a bottle of this gas, and immediately close the mouth with the thumb protected by a piece of paper: an explosion takes place with the deposition of sulphur.

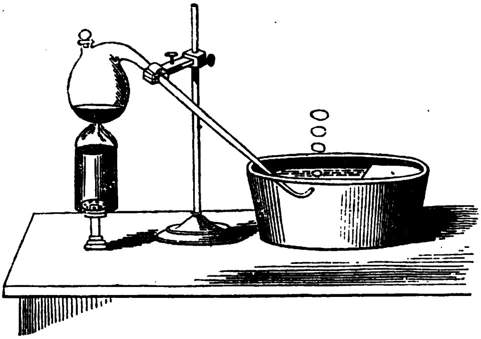
3. Generate the gas in a flask fitted with a cork and bent tube passing into a solution of arsenious acid (arsenic of commerce): an orange-coloured precipitate is formed of a sulphuret of arsenic. Sulphuretted hydrogen is much used in this way as a test for metals.



4. Transmit, as in the last experiment, a current of the gas through liquid ammonia: a solution of hydrosulphuret of ammonia is formed. This solution is much used as a reagent.

## *Phosphuretted Hydrogen*—$PH_3$.

**61.** *Experiment* 1. Put some thin slices of phosphorus into a small retort, and fill it completely with a mixture of *lime* and warm water; insert the beak of the retort in a vessel containing warm water; boil the mixture: bubbles of phosphuretted hydrogen gas are given off, which, escaping



into the air, ignite spontaneously, and form beautiful rings of smoke.

2. Invert a test-tube filled with water over the beak of the retort in which the gas is being formed: the tube is soon filled with the gas. Observe that the gas is colourless and transparent like common air; cover the mouth of the tube with the forefinger, and transfer the gas into a jar of oxygen standing on the shelf of the pneumatic trough; the bubbles as they rise into the jar catch fire, giving a splendid flash of light.

## CHLORINE—Cl.

**62.** *Preparation.* Introduce into a retort hydrochloric acid and black oxide of manganese, so as to form a thin paste; heat the mixture with an Argand lamp: chlorine gas is speedily given off, which may be recognised by its peculiar colour and suffocating odour; receive the gas over warm water in a small pneumatic trough (or by displacement, see Art. **54.**). The action is represented by the following symbols:—

$$\begin{aligned}&\text{2 eq. hydrochloric acid} + \text{1 eq. oxide of manganese}\\ &= 2\,HCl + Mn\,O_2\\ &= Cl + Mn\,Cl + 2\,HO\\ &= \textit{1 eq. chlorine} + \text{chloride of manganese and 2 eq. water.}\end{aligned}$$

### *Experiments.*

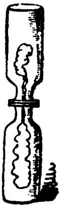
1. Repeat Exp. 1., Art. **22.**

2. Let fall powdered antimony into a bottle of this gas: the metal ignites spontaneously, and forms a beautiful shower of flame. Various other metals ignite spontaneously in this gas, and form *Chlorides.*

3. Put a piece of red calico moistened with water into a bottle of chlorine: the colour is speedily discharged.

### *Hydrochloric Acid*—H Cl.

**63.** To obtain this acid in the gaseous state, introduce into a retort common salt and as much sulphuric acid as will form a thin paste; apply the flame of an Argand lamp, and receive the gas by displacement, as it is highly soluble in water. See Art. **54.**

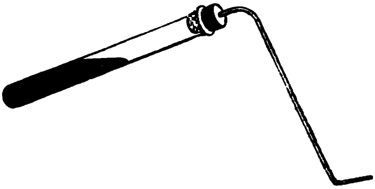


*Experiment.* Place a bottle of this gas over a bottle of ammoniacal gas: the gases combine and form dense white fumes of hydrochlorate of ammonia.

*Liquid hydrochloric acid* may be prepared in considerable quantities by transmitting a current of the gas through water; it may also be made on a small scale, after the manner of preparing nitric acid (see page 56.), taking care, in this case, to put water into the receiver *b.*

### *Cyanogen*—Cy, *or* $C_2N$.

**64.** *Experiment.* Introduce a few grains of cyanide of mercury (Hg Cy) into a test-tube fitted with a cork and bent tube; apply the flame of a spirit-lamp: cyanogen gas is given off; ignite the gas as it issues from the small tube: it burns with a beautiful violet flame.



# CHAP. VI.

COMPOSITION OF VEGETABLE SUBSTANCES. COMPOUND ORGANIC SUBSTANCES IN PLANTS. FERMENTATION. DIASTASE. GERMINATION OF PLANTS. STRUCTURE AND FUNCTIONS OF PLANTS. FOOD OF PLANTS.

## COMPOSITION OF VEGETABLE SUBSTANCES.

65. WHEN a piece of straw, or any dried vegetable substance, is held in the flame of a candle, the greater portion is consumed in the form of gases, and only a very small portion, called the ash, is left behind. That portion which burns away is called the *organic* part of the plant, and that which remains, the ash, is called the *inorganic* part. The organic part of plants consists of four elementary substances, viz. carbon, oxygen, hydrogen, and a small quantity of nitrogen. The inorganic part consists of the following earthy substances, viz. potassa, soda, lime, silica, magnesia, alumina, oxide of iron, oxide of manganese, sulphuric acid, phosphoric acid, and chlorine. Although the ash forms a very small part of plants, yet it seems to be as essential to their growth and existence as any of the elements composing the organic part. The proportion in which these substances are found varies in different plants, and even in different parts of the same plant. The following Tables, by Boussingault and Johnston, give the composition of the organic as well as of the inorganic parts of some of our most valuable plants.

When all moisture has been evaporated, 100 lbs. of each *vegetable substance* is composed as follows:—

| | Carbon. | Oxygen. | Hydrogen. | Nitrogen. | Ash. | |
|---|---|---|---|---|---|---|
| Wheat - - | 46·1 | 43·4 | 5·8 | 2·3 | 2·4 | 100 |
| Oats - - - | 50·7 | 36·7 | 6·4 | 2·2 | 4·0 | 100 |
| Peas - - - | 46·5 | 40·0 | 6·2 | 4·2 | 3·1 | 100 |
| Potatoes - - | 44·0 | 44·7 | 5·8 | 1·5 | 4·0 | 100 |
| Wheat straw - - | 48·4 | 38·9 | 5·3 | 0·4 | 7·0 | 100 |
| Oat straw - - | 50·1 | 39·0 | 5·4 | 0·4 | 5·1 | 100 |
| Pea straw - - | 45·8 | 35·6 | 5·0 | 2·3 | 11·3 | 100 |

In 100 lbs. of ash we have the following composition :—

| | Wheat. | Oats. | Barley. | Wheat Straw. | Oat Straw. |
|---|---|---|---|---|---|
| Potassa - - | 19 | 6·0 | 12 | 0·5 | 15 |
| Soda - - - | 20·5 | 5·0 | 12 | 0·75 | trace |
| Lime - - - | 8 | 3·0 | 4·5 | 7·00 | 2·75 |
| Magnesia - - | 8 | 2·5 | 8 | 1·00 | 0·50 |
| Alumina - - | 2 | 0·5 | 1 | 2·75 | trace |
| Oxide of iron - | 0 | 1·5 | trace | 0 | trace |
| Silica - - - | 34 | 76·5 | 50 | 81·00 | 80·00 |
| Sulphuric acid - | 4 | 1·5 | 2·5 | 1·00 | 1·50 |
| Phosphoric acid - | 3·5 | 3·0 | 9 | 5·00 | 0·25 |
| Chlorine - - | 1 | 0·5 | 1 | 1·00 | trace |
| | 100 | 100 | 100 | 100 | 100 |

**66.** Hence it appears that different kinds of plants must exhaust the soil of different proportions of inorganic matter: thus, for example, 100 lbs. of the ash of wheat carry off 19 lbs. of potassa and 34 lbs. of silica, while that of barley only 12 lbs. of potassa and as much as 50 lbs. of silica. Thus it is that some land will suit one kind of vegetables and not another kind; and hence it is that two successive crops of *different* kinds of plants may grow on land, when two successive crops of the *same* kind would exhaust the soil of some of its most essential constituents. It has, however, been found, that when any one of the alkalies is absent from the soil, its place may be to a certain extent supplied by another alkali without injury to the vegetation: thus when a soil is deficient in potassa and soda, then lime (an alkaline earth) will in some measure supply their place in the ash of the plant.

**67.** As plants carry off, year after year, certain portions of organic as well as inorganic substances from the land in which they grow, it becomes necessary, in most soils, that these substances should be restored to the land in the form of manures.

### COMPOUND ORGANIC SUBSTANCES IN PLANTS.

**68.** In the organic part of plants, the four elements of which it is composed are found in the plant in the form of distinct compounds; the most abundant of these are lignine or woody fibre, starch, gum, sugar, gluten, and albumen. The first four substances are composed of carbon and water only, and the two last substances contain nitrogen, in addition to carbon, oxygen, and hydrogen.

The composition of the first four substances is as follows:—

| | Composition | may be represented. |
|---|---|---|
| Lignine - - | $C_{12}\ H_8\ O_8$ | 12 eq. carbon and 8 eq. water. |
| Starch - - | $C_{12}\ H_{10}\ O_{10}$ | 12 eq. carbon and 10 eq. water. |
| Gum - - | $C_{12}\ H_{11}\ O_{11}$ | 12 eq. carbon and 11 eq. water. |
| Grape sugar - | $C_{12}\ H_{12}\ O_{12}$ | 12 eq. carbon and 12 eq. water. |

The only difference in the composition of these compounds is, that they contain different proportions of the elements of water.

Most of vegetable compounds are characterised by the following circumstances:—1. By being composed of the same elements; 2. By the facility with which they undergo decomposition; 3. By the facility with which many of them are converted into each other, especially when a substance containing nitrogen is present; 4. By the impracticability of forming them by the direct union of their elements.

These distinct compounds, which exist ready formed in the vegetable, are called *proximate principles;* thus sugar and *gum are proximate* vegetable principles.

*Experiment.* Put some wheat flour in a fine muslin bag, and knead or work it with your fingers, while a small stream of water is poured upon it; continue the process until the water ceases to be milky: the substance remaining in the bag is a grey adhesive matter like birdlime, callen *gluten;* allow the milky portion which has been washed from the bag, to subside; decant off the clear liquid: the white deposition is called *starch;* take the clear liquid and boil it: white flakes of *albumen* are formed, a substance very similar in its nature to the white of an egg. Gum and sugar are dissolved in the water.

Perform the same process with grated potato: in this case, fibrous matter is left in the bag, the other portions being the same as in the preceding experiment.

**69.** Lignine, starch, gum, and sugar, being so similar in composition, may readily be converted into each other. Thus, for example, starch may be converted into gum by roasting at a temperature above that of boiling water; lignine may be converted into gum by the action of strong sulphuric acid; and the gum thus formed may be converted into sugar by adding water, and boiling the mixture for some hours; and so on to other cases of transformation.

### *Experiments.*

1. Dissolve some starch in boiling water: a thick jelly is formed, which after being dried has the appearance of glue; this jelly is insoluble in cold water, and is rendered blue by the addition of a solution of iodine (see Exp. 2., Art. **21.**). To the thick solution of starch add an infusion of vegetated barley of the malting: the starch grows more liquid, and in a short time its consistence entirely disappears; evaporate to dryness, and a *yellow* jelly-like mass is obtained, which is now readily dissolved by *cold* water, whereas starch is insoluble in *cold* water. To a solution of this substance add a solution of iodine: a red wine colour is produced. This yellow substance is a gum called *dextrine;* it is used in the place of gum-arabic for stiffening calico.

There is evidently some active agent in the vegetating barley, which has produced these changes in the starch: this agent has been called ***diastase***.

2. Boil some diluted sulphuric acid (one of acid to twelve parts of water) in a porcelain dish; add gradually some starch paste: the starch is dissolved; test a portion of the solution by means of a solution of iodine: a red wine colour is produced, as in the last experiment; continue the boiling for a short time longer, and the iodine will cease to produce any change of colour. Take the liquid in the evaporating dish, and add to it powdered chalk until the acid is neutralised, and allow the sulphate of lime to subside: the clear liquid is sweet, and crystals of *sugar* may be obtained by evaporating a portion of the water by a slow heat. In this process no gas is given off, and the acid suffers no change. The only difference in the composition of starch and sugar is, that the latter contains more of the elements of water than the former.

Berzelius designates this peculiar action exerted by the sulphuric acid in converting starch into sugar the *Catalytic Force*, or the force of *Catalysis*.

**70.** *Fermentation.* This term is used *generally* to express those changes that are spontaneously effected in organic substances by the re-action of their elements. Thus, when a solution of grape sugar, to which ferment or common yeast has been added, is kept for some time at a moderate heat, the mixture froths up, in consequence of the escape of carbonic acid gas, the sweet taste of the solution gradually disappears, and when the *fermentation* has ceased, spirit or alcohol is found in the water. This spirit is given off in a concentrated form by evaporation, at a temperature below that of boiling water. Alcohol ($C_4\ H_6\ O_2$) contains less oxygen and carbon than sugar; hence the escape of carbonic acid in order to change the sugar into *alcohol*. Thus sugar, or $C_{12}\ H_{12}\ O_{12}$, becomes $2\ C_4\ H_6\ O_2$, or 2 eq. alcohol and $4\ CO_2$, *or* 4 eq. carbonic acid. Yeast, as well as all substances which have the property of *inducing* or exciting fermentation, contains nitrogen, in addition to carbon, oxygen, and hydrogen.

**71.** When a mixture of diluted spirit and yeast is exposed to the air, oxygen is absorbed, and *acetic acid* or vinegar is formed. The composition of dry acetic acid is $C_4 H_3 O_3$; that is, it may be represented by 4 eq. carbon and 3 eq. water. Hence the action may be represented as follows:—

1 eq. alcohol + 4 eq. ogxyen $= C_4 H_6 O_2 + O_4$
$= C_4 H_3 O_3 + 3 HO$,
or 1 eq. acetic acid + 3 eq. water.

In both of these cases of fermentation the yeast merely acts as a stimulating agent.

**72.** Besides the proximate vegetable principles already enumerated, there are several vegetable acids, oils, fatty matters, and the peculiar substance called diastase, which produces an important action in relation to the growth of plants.

*Vegetable Acids.* The most common vegetable acids are, acetic acid (vinegar), malic acid (the acid of apples) oxalic acid (from common sorrel), tartaric acid (in grapes), citric acid (the acid of lemons).

## GERMINATION. DIASTASE.

**73.** When a seed is planted it begins to sprout, that is, it shoots a sprout upwards into the air, and sends a root downwards into the soil. At this stage of the life of the young plant it must live upon the starch and gluten contained in the seed alone. In order to render these substances soluble in water, and thereby available for the food of the plant, there is formed out of the gluten, at the base of the germ, the peculiar substance called diastase. This substance renders the starch soluble in the sap, and it is thus conveyed to the shoot and root of the young plant. The starch in this state of solution becomes sugar. As the plant advances in its growth it begins to have leaves, and at this stage the sugar is changed into woody fibre, which forms the stem. By the time the starch and gluten are exhausted from the seed, the plant has acquired all the functions necessary for taking up food from the air and the soil. A similar process takes place in the formation of malt, where the germination of the barley is stopped when the sugar is formed.

## STRUCTURE AND FUNCTIONS OF PLANTS. FOOD OF PLANTS.

74. A complete plant has three parts which are essential to its growth: a root, which throws out fibres into the soil; a trunk or stem, which rises into the air; and leaves, which present an extended surface to the action of the air. Each of these three parts performs peculiar functions or offices in the growth of the plant.

1. The *trunk* or stem consists of three parts: in the centre is the *pith*, next the pith is the *wood*, and the *bark* incloses the whole.

The *pith* consists of very small horizontal tubes; the *wood* and *inner bark* are made up of longitudinal tubes connected together for conveying the sap between the roots and leaves; the vessels in the wood convey the sap from the roots to the leaves, and the vessels in the inner bark convey the sap from the leaves to the roots: thus in a growing plant there are currents of sap continually ascending and descending.*

2. The *root* on leaving the stem has the same structure as the trunk; but the finely-extended tendrils consist of one

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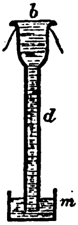
* The ascent of the sap probably, in some measure, depends on the principle of *endosmose* and *exosmose*. A tube *d b*, having a piece of bladder tied over its upper end *b*, is filled with water and inverted with its open end in a cup of mercury *m*. On the principle of endosmose, the water passes through the fine pores of the bladder, and is evaporated from the outside surface of the bladder by the air. In the course of a few hours the mercury will have ascended for some distance in the tube *d*. If the ascent of the sap in plants depends on this principle, the leaves will constitute the surface from which the water is being evaporated, and the tubes in the wood will form the channel of the ascending fluid. There are other modes in which this principle acts in reference to vegetable life. However, it must be admitted, *that there is something* connected with the vital principle of organism *which lies above and* beyond the province of physical science.



white uniform spongy mass, for the purpose of absorbing liquid food from the soil.

3. The *leaf* consists of fibres, which are continuations o the wood, together with the green portion, which is a continuation of the bark. The under part of the leaf is full of pores, which communicate with the hollow tubes of the inner bark.* It has already been explained (Exp. 6., Art. **15.**, and Art. **18.**) that in the day-time the leaves are continually absorbing carbonic acid gas from the air, and throwing off oxygen: thus carbonic acid is decomposed by the plant—the carbon is retained as food, while the oxygen is rejected. The reverse of this process is going on at night, but so slowly as scarcely to interfere with the general effect. Carbonic acid also enters the plant through the roots. Some *suppose* that carbon enters the plant by the roots in the form of *ulmic acid*, a substance composed of carbon and water only.

**75.** The elements composing the organic part of plants are always absorbed in a state of combination, and the substances forming the inorganic part must be in a state of solution, in order to be sucked in by the roots. The food of plants must contain the various elements which enter into their composition. In general, the substances which afford this food, are carbonic acid, water, and ammonia, derived from the air as well as the soil; and certain saline and earthy substances, derived exclusively from the soil. Light and heat (and probably electricity) stimulate the functions of plants, and are absolutely necessary to their growth and full development. Light is also essential to the formation of the colouring matter in plants.

It will now be easy to see how the plant should form woody fibre, starch, sugar, gum, or vinegar, all of which substances consist of carbon and water only, united in different proportions. Ammonia and nitric acid supply the plant with nitrogen.

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* For a full description of *all* the parts and functions of plants, see "Balfour's Botany."

## CHAP. VII.

SOILS. THEIR COMPOSITION. ORGANIC AND INORGANIC PARTS. SALINE AND EARTHY PARTS. PHYSICAL CHARACTER OF SOILS. TO SEPARATE THE SAND FROM THE CLAY. TO DETERMINE THE QUANTITY OF LIME, OF ORGANIC MATTER, AND OF SALINE MATTER, IN A SOIL. ORIGIN OF SOILS. MECHANICAL PROPERTIES OF SOILS. CHEMICAL PROPERTIES OF SOILS.

### COMPOSITION OF SOILS.

**76.** Soils, like plants, are composed of organic as well as of inorganic matter.

The organic part of soils is chiefly derived from the remains of vegetable and animal substances. Peaty soils contain a large proportion of organic matter, while good wheat lands contain only about one-twentieth of their whole weight. This organic matter in the soil has been called humus, which, by the action of alkaline substances, is resolved into ulmic and humic acids. As the vegetable matter undergoes decay, this organic portion of the soil also gives to the land the various inorganic substances found in its ash.

**77.** The inorganic part of soils consists of certain *saline* soluble substances, and of certain *earthy* insoluble substances.

1. The *saline soluble substances* consist, in general, of common salt, sulphates of soda and magnesia, gypsum, with small portions of the nitrates of potassa, soda, and lime, and of the chlorides of calcium, magnesium, and potassium, together with ammoniacal salts. From these soluble compounds the plant obtains nearly all the saline matter contained in its ash. The rain dissolves these saline substances,

and carries them into the subsoil; but in dry warm weather they reascend to the surface, and are thus brought in contact with the roots of the growing plant. Thus fine warm weather accelerates the ripening of corn and other valuable grain.

2. The *earthy insoluble substances* in the soils never constitute less than nine-tenths of their whole weight. The *principal* ingredients of this earthy matter are *silica* in the form of sand, *alumina*, mixed with sand, in the form of *clay*, and *carbonate of lime*. Where the soil has a red colour, the *oxide of iron* is generally present. Minute traces of *phosphate of lime* may also be detected in most of good soils.

### PHYSICAL CHARACTER OF SOILS.

**78.** The relative proportions of sand, clay, and lime in a soil give it a peculiar physical character. When a soil contains only a small proportion of clay, it is called a *sandy soil;* when the quantities of sand and clay are nearly equal, it is called a *loamy soil*, or *clay loam*, according as the quantity of sand is greater or less than the clay; when the clay is much in excess, it is called *clay loam*, or *strong clay*, as the case may be. Good arable land rarely contains more than one third part of its weight of clay.

**79.** *To separate the sand from the clay in a soil.* Take about half an ounce of soil, and boil it in about half a pint of water, in a porcelain dish, until it is completely diffused through the water; after shaking let the mixture stand for a minute, to allow the sand to settle to the bottom of the vessel, while the clay remains suspended in the fluid; pour off the water with the floating clay into another vessel, and allow the clay now to settle. The sandy portion of the soil will be found in the first vessel, and the clayey portion at the bottom of the second. The sand and clay may now be dried and weighed separately, and the relative weights will give the proportion in which they subsist in the soil.

**80.** If a soil contains more than one-twentieth of its weight of carbonate of lime, it is called *marl;* and if more than one-fifth, it is called *calcareous soil.*

*To determine the quantity of lime in a soil.* Take 100 grains of the soil (which has been previously heated to redness, to destroy the vegetable matter) and diffuse it through about half a pint of distilled water; add about an ounce of hydrochloric acid, and allow the mixture to stand for a few hours, observing to stir it time after time. Bubbles of carbonic acid are given off. After the action has ceased, pour off the clear liquid; dry and then heat the residue to redness, and weigh it: the loss is nearly the weight of lime and carbonate of lime in the soil.

**81.** *To determine the quantity of organic matter.* Dry about an ounce of the soil on paper in an oven, at a heat which does not char the paper; burn about 200 grains of this dry soil: the loss is nearly the weight of the organic matter contained in it.

**82.** *To determine the quantity of saline matter.* Take 2 lbs. of dry soil, and boil it in about a quart of distilled water; after allowing the solid matter to subside, pour off the clear liquid, and evaporate to dryness at a moderate heat; weigh the residue, and it will give the quantity of soluble saline matter in the soil. In a good soil this saline matter may weigh, upon an average, about 20 grains.

### ORIGIN OF SOILS.

**83.** Soils owe their origin to the disintegration or gradual crumbling down of rocks, by the action of water, frost, air, and various chemical agents. Hence soils, in general, derive their peculiar character from the geological strata upon which they lie, or from the nature of the rocks in the adjacent hills or mountains.

### MECHANICAL PROPERTIES OF SOILS.

**84.** Sandy and marly soils are heavy, while peaty soils are light. Strong clays and peaty soils absorb and retain moisture; hence they are damp and cold; hence, especially, the necessity for draining such soils. Sandy soils neither absorb nor retain much moisture; hence such soils become scorched with the heat of summer, and the plants growing upon them are burned up. In rainy seasons, however, sandy soils frequently sustain a luxuriant vegetation, while the plants upon a clayey land almost perish from the excess of moisture.

**85.** Heat causes clay and peat to contract ; in doing so, the soil compresses the roots of the plants, and prevents the access of air, and thus the growth of the plant is retarded.

**86.** The absorbent power of clay is useful in a soil, for during the hot and dry season of the year, in the cool period of the night, the clay absorbs the dew that falls upon it, and retains the moisture with great tenacity.

**87.** In order that plants may come to perfection, it is necessary that the soil on which they grow should attain a certain degree of warmth. Damp lands are cold, for the continual evaporation of the moisture carries off the heat of the sun ; hence the necessity of drainage.

**88.** These observations show the value of a due admixture of clay and sand in order to form a mixture having all the mechanical qualities of a fertile soil, where the earthy constituents are so adjusted that "the loose and porous qualities of the one are corrected by the plastic and retentive qualities of the other." It is a remarkable fact, that a mixture of alumina, silica, and lime, absorb gaseous matter as well as moisture, better than any of these earths taken by itself.

### CHEMICAL PROPERTIES OF SOILS.

**89.** Soils not only sustain a plant in an erect position and afford it food, but they are the medium in which various chemical actions are gradually and constantly going on, in the preparation of different substances essential to the growth of plants. Thus lime is constantly decomposing vegetable and animal matter in the soil, and thereby preparing food for the plant. Thus organic substances in the soil aid in absorbing ammonia and carbonic acid from the air. Thus little grains of alkaline silicates are gradually reduced to powder, and in this state water dissolves the alkaline matter. (See Exp. 1., Art. 28.)

**90.** A fertile soil should not only contain all the elements essential to the growth of a plant, but they should exist in a due proportion. A deficiency of one substance, or an excess of another, may equally contribute to deteriorate the quality of the land. Hence the utility of artificial applications to land, whereby the farmer is enabled to supply what may be deficient, or in some degree to neutralise the influence of what may be in excess. The following analyses of three different soils, by Dr. Sprengel, afford a striking illustration of these remarks.

1000 parts of each soil contained as follows:—

| | No. 1. | No. 2. | No. 3. |
|---|---|---|---|
| Fine earthy and organic matter | 937 | 839 | 599 |
| Siliceous sand | 45 | 160 | 400 |
| Saline soluble matter | 18 | 1 | 1 |
| | 1000 | 1000 | 1000 |

1000 parts of the fine earthy and organic matter contained:

| | No. 1. | No. 2. | No. 3. |
|---|---|---|---|
| Organic matter | 97 | 50 | 40 |
| Silica | 648 | 833 | 778 |
| Alumina | 57 | 51 | 91 |
| Lime | 59 | 18 | 4 |
| Magnesia | 8·5 | 8 | 1 |
| Oxide of iron | 61 | 30 | 81 |
| Oxide of manganese | 1 | 3 | ½ |
| Potassa | 2 | trace | trace |
| Soda | 4 | — | — |
| Ammonia | trace | — | — |
| Chlorine | 2 | — | — |
| Sulphuric acid | 2 | ¾ | — |
| Phosphoric acid | 4·5 | 1¾ | — |
| Carbonic acid | 40 | 4½ | — |
| Loss | 14 | — | 4½ |
| | 1000 | 1000 | 1000 |

No 1. is a highly fertile soil, which had grown corn and pulse crops *without* the application of any manure. This soil seems to contain all the essential constituents of plants. No. 2. is a fertile soil which required to be manured with gypsum. The analysis indicates a deficiency of soluble saline matter, with only traces of potassa, soda, and sulphuric and other acids. No. 3. is a barren soil; it is deficient in organic matter; potassa, soda, &c. are almost wanting; lime, oxide of iron, and silica seem to be largely in excess. In order to render this soil productive, it would require, not only to have added those substances which are absent, but some other substances which would tend to neutralise the matters in excess.

## CHAP. VIII.

IMPROVEMENT OF SOILS. MECHANICAL OPERATIONS: DRAINING, PLOUGHING, ETC. MANURING: VEGETABLE, ANIMAL, AND MINERAL MANURES. SPECIAL MANURES. ROTATION OF CROPS. FALLOWING. IRRIGATION.

### IMPROVEMENT OF SOILS.

**91.** LAND may be improved by working it, that is, by mechanical operations, such as draining, ploughing, &c.; or by improving the quality of the soil by the application of manures.

### MECHANICAL MEANS OF IMPROVING LAND.

**92.** *Draining.* It has already been shown (Art. **87.**) that damp lands are cold and unproductive. The first consideration, therefore, with the farmer in reference to such soils is to have all redundant moisture carried off by means of drains. The advantages of drainage are further shown by the following circumstances. When there is too much water in a soil, the food of the plant is either washed down to the subsoil, or it enters the roots in a very diluted state. When a soil has been drained and ploughed, it is no longer close and adhesive, but permits the air to penetrate through it, and the roots to extend themselves in all directions. Moreover, a more healthful decomposition of the organic matter goes on in dry soils than in damp ones.

There are few soils which may not be benefited by drainage. It is especially beneficial to damp clay and peaty soils. When the soil is a clay with sand or gravel for the subsoil, it will be sufficient if the surface is drained: but when the soil is sandy, with clay for the subsoil, the drain should go down into the subsoil, otherwise the land will be damp and cold. To prevent the soil being washed away, the fall of drains should be gentle. Land should always be drained some time before ploughing. Drain pipes made of porous burnt clay fitting into each other are now generally adopted for agricultural purposes.

**93.** *Ploughing* in general, especially combined with drainage, allows water, air, and other gases to come in contact with the roots of the plants, destroys unhealthful acidity in the soil, and promotes the decomposition of vegetable matter.

**94.** *Subsoil* and *deep-ploughing* especially bring new mineral manure, such as lime, to the surface. Agriculturists consider that the subsoil plough should not be used until after the land has been drained for one year. The reason of this must be obvious: damp soils are merely cut by the plough, whereas dry soils are broken to powder when a heavy plough passes through them.

### MANURING AS A MEANS OF IMPROVING SOILS.

**95.** Manures are divided into three classes; viz. vegetable manures, animal manures, and mineral manures.

### VEGETABLE MANURES.

**96.** These manures serve to open the pores of the land, and to supply organic as well as inorganic food to plants. Vegetable matter may be used as a manure either in the *green* state or in the *dry* state.

*Green Manures.* When green vegetable substances are put into the soil, they undergo a rapid decay, yielding a speedy supply of food to the growing plant; on the contrary, dry manures decay more slowly, but act more permanently upon the land. The cleanings of ditches, hedge-sides, &c., turnip and potato tops, mixed with earth, and formed into a *compost heap*, constitute an enriching application to the soil. In some parts of this country turnip seed is sown at the close of harvest, and at the end of two months the green crop is ploughed into the land. Sea-weeds form a valuable green manure.

**97.** *Dry Manures.* Dry vegetable substances, such as straw, saw-dust, &c., decay very slowly; it is desirable, therefore, before applying such substances to the land, that they should be mixed with some matter which tends to promote fermentation. The droppings of cattle, urine, or animal substances of any kind, are used for this purpose. Saw-dust mixed with soil and common weeds, laid up in a compost heap, and time after time watered with the liquid manure of the farm-yard, is converted into a valuable vegetable mould. If the fermentation be not carried beyond a certain point, this compost exercises a gradual and prolonged action on the growing plants; on the contrary, if it be laid on the land when in a complete state of fermentation, the action is immediate; hence the application of the latter kind of manures to turnips and other crops which require to be brought into a condition of rapid growth. *Charcoal-powder, malt-dust, bran, rape-dust, soot, tanner's bark,* &c., are the most common dry manures in use.

### ANIMAL MANURES.

**98.** Animal manures are the most energetic in their action, in consequence of the nitrogen they contain, which exists in them in the form of ammoniacal salts: these salts are amongst the most powerful agents in promoting vegetation. The value of guano as an application to the soil depends chiefly on the quantity of ammonia which it contains. Urine also owes its efficacy to the large quantity of the salts of ammonia in its composition. According to Liebig, the air immediately in contact with the soil contains small portions of ammonia, which is being continually absorbed by the soil. The soluble portion of manures is most valuable, in consequence of the volatile substances which it contains; and hence the intelligence and industry of a farmer is shown by the care he takes of his dung-heap and liquid manure. The urine of the cattle should be collected into a tank sunk in the ground, and covered over to prevent the rain-water from mixing with it. In warm weather the mixed manure heap, or compost heap, should be watered, and a free current of air allowed to pass over it, in order to check, in some degree, the process of fermentation, which causes the carbonate of ammonia to escape into the air. In order still further to secure the volatile matters, the heap should be covered over with a layer of soil, or, in other cases, with the sulphate of lime; these earths absorb and fix the vapours, and are thus converted into valuable applications to land. Quicklime should never be put into the compost heap, for it decomposes the salts of ammonia, and thus the most valuable portion of the manure would be dissipated into the atmosphere. As there is always a loss during fermentation, the judgment of the farmer must be exercised as to the proper time for laying the fermenting manure upon his land: this time must, in some degree, depend upon the nature of the soil and crops to be reared. To cold soils, for example, fully fermented manure is most valuable, as it tends to warm the soil, and to stimulate the growth of the plant.

**99.** Boussingault gives the following analysis of an average farm-yard manure:—

In 100 parts of the manure we have

| | |
|---|---|
| Carbon - - - - - | 7·41 |
| Oxygen - - - - - | 5·34 |
| Hydrogen - - - - - | 0·87 |
| Nitrogen - - - - - | 0·41 |
| Salts and earthy substances - - - | 6·67 |
| Water - - - - - | 79·30 |
| | 100·00 |

**100.** *Bones* not only contain animal matter, but also a large quantity of earthy substances; hence the value of this substance as a manure. The composition of the bones of the cow is as follows:—

| | |
|---|---|
| Phosphate of lime | 55½ |
| Phosphate of magnesia | 3 |
| Soda and common salt | 3½ |
| Carbonate of lime | 3¾ |
| Fluoride of calcium | 1 |
| Gelatine | 33¼ |
| | 100 |

Bones are used in the form of bone-dust and broken bones; the former is more immediate in its effect, the latter more permanent. Bones are most beneficially applied to turnip crops.

**101.** *Blood and muscle*, forming the refuse in the butcher's heap, mixed with marl and other earthy substances, have been found to be a powerful manure. *Horn*, *hair*, and *wool* are used in a similar manner.

**102.** *Animal Excrements.* Horse-dung is more valuable than cow-dung, in consequence of the cow discharging more urine than the horse, which carries off soluble organic matter. The horse-dung is a *hot* manure, while cow-dung is *cold.* The horse-dung, as already shown, is chiefly used for bringing other manures into a state of fermentation. The dung of pigs, like that of the cow, is soft and *cold.*

**103.** *Night soil* is considered to be one of the most powerful of all solid animal manures.

**104.** *Pigeons' Dung.* The dung of birds is a very active manure; it unites the qualities of the liquid as well as of the solid excrements of other animals: it is usually applied with a mixture of coal ashes.

**105.** *Guano* is chiefly the excrement of sea-fowl; it has been found in vast quantities on the rocky parts of the coast of Peru, and at Ichoboe, an island on the west coast of Africa. This manure has been brought to this country, and sold for 9*s.* to 12*s.* a cwt. It has been successfully applied to crops of turnips, potatoes, oats, barley, &c. It is applied in different proportions, varying from 1 to 4 cwts. per acre. When applied to the land, it is mixed with fine dry sand, or with gypsum. Probably no manure contains so many of the ingredients necessary to the growth of plants as guano. The following analysis of African guano was made by the late Dr. Fownes:—

| | |
|---|---|
| Oxalate of ammonia, uric acid, traces of carbonate of ammonia, and animal matter - - - | 66·2 |
| Phosphate of lime and magnesia - - - | 29·2 |
| Phosphates and chlorides of alkalies - - - | 4·6 |
| | 100·0 |

**106.** *Urine* is rich in various compounds of ammonia; it should be applied in a fresh state, for when it putrefies a considerable loss of urea takes place. It may be thrown over the land by means of a water-cart. When sulphuric acid is added to urine, it combines with and fixes the ammonia: by evaporation a dry powder is obtained, which is called *sulphated urine;* this is said to form a valuable artificial manure.

## MINERAL MANURES.

**107.** *Lime, Shell-sand, and Marl.* Lime is the most important of all the mineral applications to land. It serves a mechanical purpose by giving a proper consistency to soils, and it acts chemically by decomposing various organic substances, at the same time absorbing and fixing their gaseous products, and rendering vegetable as well as mineral substances soluble which were not so before.* Mr. Moffat, in an able paper (published in the "Journal of the Northumberland Agricultural Society" for the year 1849), adduces the following experiment to illustrate the mode in which lime acts on the soil:—

*Experiment.* "Take some saw-dust, or any fibrous matter, and boil it in water so as to extract all its soluble matter; wash it well with cold water, and strain, so as to leave it only in a moist state; then add to it one fifth part of caustic lime, and close the mixture up in a bottle for two or three months. After this period you will find the lime to have assumed a brownish colour, effervescent when vinegar is poured upon it, which indicates the presence of carbonic acid; and when water is again boiled with the mass, it will gain a fawn colour, and by evaporation leave a fawn-coloured powder, consisting of lime combined with vegetable extract. The saw-dust previous to the action of the lime was perfectly insoluble in water; it is now converted into a brownish powder, which dissolves in large quantity in water. Now this is precisely an example of the change produced by the action of lime in a caustic state upon the insoluble fibrous matters of the soil." Mr. Moffat further observes:— "Caustic lime decomposes all the salts and combinations of ammonia, combining with their acids by reason of its stronger alkaline affinity, and dissipating the ammonia into the atmosphere; hence lime should never be applied with guano, nor farm-yard dung, as a great portion of the nutritive quality of these manures resides in the salts of ammonia they contain." When vegetable matter abounds in a soil, a considerable portion of lime may be used to promote the decomposition. Stiff clay lands, after draining, should be well limed; on the contrary, light lands, where there is neither much moisture nor vegetable matter, do not require such a quantity. Striking effects are produced by a due application of lime to pasture and arable lands.

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* Insoluble compounds of silica and potassa exist in many of our rocks: now when these earths are crushed and mixed with lime and water, it has been found that, after a certain time, the silica and potassa are converted into a soluble form. No doubt these changes take place, to a limited extent, in the soil.

The effects of lime gradually disappear, and after a few years the land returns to its original state, unless fresh lime be added.

Lime is removed from the soil,—first, by sinking through the loose soil; secondly, by rains which wash it away; and thirdly, by the crops carrying off certain portions of lime in the form of the carbonate.

**108.** *Marl and shell-sand*, besides other fertilising matters, contain a large quantity of carbonate of lime; their action upon land is similar to that of *mild* lime. Sulphuret of iron (iron pyrites) is found in some soils. This insoluble substance has no chemical action, but when it has been for a length of time exposed to the action of the air, it absorbs oxygen, and is converted into sulphate of iron (green vitriol), which is highly soluble, and injurious to plants. Now the addition of carbonate of lime decomposes this salt, forming sulphate of lime and the inert oxide of iron, with the escape of carbonic acid gas.

**109.** *Sulphate of lime* may be used with advantage for all kinds of crops, but it is especially applicable to clover, pea, and bean crops. The sulphates generally supply sulphur to plants.

**110.** *Sulphate of magnesia*, as a top dressing, has been applied with great benefit to young wheat.

**111.** *Sulphate of soda* (Glauber salts) has been beneficially used for turnip crops; and, mixed with nitrate of soda, it has given abundant crops of potatoes.

**112.** *Chloride of sodium* (common salt) has generally a fertilising influence on high or sheltered lands situated at a distance from the sea.

**113.** *Kelp* (the ash of sea-weeds) and *wood-ash* are well known to have a beneficial action on all kinds of soils.

**114.** *Chloride of potassium* (the residue of the nitre refiners) is sometimes used as a dressing for grass-land.

**115.** *Nitrates of potassa and soda.* These have been found especially beneficial to young plants. The nitric acid which they contain supplies nitrogen to the vegetable, and the potassa and soda are equally fertilising; applied at the rate of about 1 cwt. per acre, they promote the growth of young corn and grass.

**116.** *Gas-liquor* contains a large quantity of ammonia; it therefore forms, when diluted with five or six times its weight of water, a superior manure for grass-lands or crops generally. Sulphuric acid, or gypsum, is sometimes added, to fix the ammonia in the gas-liquor.

**117.** *Special Manures.* As plants differ in their composition, so different plants evince a predilection for different kinds of food. Ammonia, nitrate of soda, and lime promote the growth of all plants. Lime, especially in well drained soils, tends to bring the fruit or seeds of plants to perfection, and thus to bring in an early harvest. Gypsum promotes the growth of red clover, and phosphate of magnesia has a similar effect upon potatoes; and so on to other cases.

The specific action of particular manures on the growth of certain plants is a remarkable and interesting fact. Even certain manures promote the development of particular parts of the plant; thus, for example, manganese added to the soil improves the flowers of the rose bush.

**118.** *Mixed saline Manures.* A mixture of lime and common salt is recommended as an excellent manure. A mixture of sulphate and nitrate of soda, as a top dressing, has been found to produce remarkable effects on the growth of potatoes; and so on to other cases. It appears that the application of mixed saline substances is calculated to produce more beneficial results than when these substances are used alone. Hence it is that guano (which contains several saline substances) is found to act so beneficially on almost every kind of crops.

### ROTATION OF CROPS.

**119.** The composition of soils should have a relation to the kind of plants which they are intended to grow. It is well known to botanists that certain species of plants grow naturally on soils of a particular formation; thus, mare's-tail grows abundantly on the margin of rivers where silica abounds. When a particular species of plant has been grown for a length of time on a soil, that soil becomes exhausted of the inorganic matter adapted to the growth of that particular plant. Now different plants extract from soils different proportions of the inorganic matter contained in *them.* (See Art. **66.**) Hence a succession of crops of different vegetables may be raised upon the same soil, when two successive crops of the same vegetable could scarcely be reared. Thus barley grows well after a crop of turnips; oats after a crop of grass; wheat after crops of beans and potatoes. The following is a specimen of a six years' rotation of crops*: —

1. Wheat; 2. Turnips; 3. Barley; 4. Seeds; 5. Oats; 6. Potatoes.

The following general rule should be observed in the choice of the rotation of crops: viz. "plants which require *chiefly* the same kind of food should not be grown in succession;" thus plants which are grown for their roots, grow best after those which are grown for their seeds.

Clover adds fertility to the soil, and hence an abundant crop of corn may be obtained after a crop of clover. In this way the use of clover has to a great extent superseded the system of fallowing.

**120.** *Fallow.* When land has been exhausted by a succession of crops, its exhausted resources are resuscitated by manuring, and allowing it to lie dormant, exposing it at the same time (by ploughing, &c.) to the action of the air and moisture.

**121.** IRRIGATION. When water is allowed to remain on land, it is injurious to vegetation; but the occasional flow of water over the surface of lands, as in our irrigated meadows, carries with it various fertilising substances.

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* "Antisell's Chemistry."

## LIST OF CHEMICALS AND APPARATUS ADAPTED TO THE EXPERIMENTS CONTAINED IN THIS TREATISE.

### *List of Chemicals.*

| | | s. | d. |
|---|---|---|---|
| Acid, Arsenious | oz. | 0 | 3 |
| „ Hydrochloric | lb. | 0 | 3 |
| „ Nitric | lb. | 1 | 4 |
| „ Oxalic | oz. | 0 | 3 |
| „ Sulphuric | lb. | 0 | 3 |
| „ Tartaric | oz. | 0 | 3 |
| Alum | lb. | 0 | 3 |
| Ammonia, liquid concentrated | lb. | 1 | 6 |
| „ Carbonate | lb. | 1 | 0 |
| „ Hydrochlorate | lb. | 1 | 0 |
| „ Oxalate | oz. | 1 | 0 |
| Antimony, Metallic | lb. | 1 | 6 |
| „ Sulphuret | lb. | 1 | 0 |
| Barium, Chloride | oz. | 0 | 2 |
| Baryta, Nitrate | oz. | 0 | 2 |
| Camphor | oz. | 0 | 8 |
| Clay, Stourbridge or Pipe, for luting | lb. | 0 | 2 |
| Copper Leaf | book | 0 | 3 |
| „ Nitrate | oz. | 0 | 3 |
| „ Sulphate | lb. | 0 | 6 |
| Distilled Water | per gall. | 0 | 6 |
| Gold Leaf | book | 1 | 9 |
| Iodine | oz. | 2 | 0 |
| Iron, Sulphate | oz. | 0 | 3 |
| „ Sulphuret | lb. | 0 | 6 |
| Lead, Acetate | lb. | 0 | 9 |
| „ Oxide, letharge | lb. | 0 | 6 |
| Lime, Hydrochlorate | oz. | 0 | 3 |
| Litmus | oz. | 0 | 6 |
| Magnesia, Sulphate | lb. | 0 | 6 |
| Manganese, Black oxide, in powder | lb. | 0 | 3 |
| Mercury | lb. | 5 | 6 |
| „ Chloride (corrosive sublimate) | oz. | 0 | 6 |
| „ Nitrate | oz. | 1 | 0 |
| Phosphorus | oz. | 0 | 9 |

| | | s. | d. |
|---|---|---|---|
| Platinum, Wire and Sheet | drachm | 0 | 5 |
| Potassa, fused in pipes | oz. | 0 | 6 |
| „ Carbonate | lb. | 0 | 9 |
| „ Chlorate | oz. | 0 | 4 |
| „ Bichromate | oz. | 0 | 2 |
| „ Nitrate | lb. | 0 | 8 |
| „ Prussiate | oz. | 0 | 3 |
| Potassium | grain | 0 | 1 |
| Silver, Nitrate, Crystals | drachm | 0 | 8 |
| Soda, Carbonate | lb. | 0 | 3 |
| „ Sulphate | lb. | 0 | 6 |
| Spirit, Pyroligneous, for spirit-lamp | pint | 1 | 6 |
| Sulphur, Sublimed | lb. | 0 | 3 |
| Tin, Foil | oz. | 0 | 3 |
| Tincture, Galls | oz. | 0 | 4 |
| „ Litmus | oz. | 0 | 6 |
| „ Red Cabbage | oz. | 0 | 6 |

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## *List of Apparatus.*

Bladders, plain, *6d.* each; mounted, 1*s.* 6*d.*
Cork Borers, set of five, 2*s.* 6*d.*
Crucibles, fire-clay, 4*d.* a dozen.
Evaporating Basins, from 6*d.* to 2*s.* each.
Filtering Paper, from 1*s.* 6*d.* to 2*s.* per quire.
Flasks, from 6*d.* upwards.
„ with tubes for making gases, from 1*s.*
Furnace Iron, with chimney, 6*s.*
„ „ with sand-bath, &c., 30*s.*
„ Chauffers, 2*s.* 6*d.* each.
Funnels, glass, from 6*d.* to 2*s.* each.
Gas Jars, plain, 1*s.* each.
„ stopped, 1*s.* 6*d.* each.
„ capped, 2*s.* each.
Gas-holder, small, 1*l.* 2*s.*
The Author's Gas-holder, with Oxyhydrogen Blow-pipe, 1*l.* 4*s.*
Ladles, Iron, for supporting ignited Phosphorus, &c., 6*d.* each.

Lamps, spirit, 6*d.* each.
„ Argand, oil, with chimney, 5*s.* 6*d.*
Mortar and Pestle, Wedgewood, 2*s.*
Pneumatic Trough, 7*s.* to 10*s.*
Test or Precipitating Glasses, 6*d.* each.
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Retorts, glass, from 9*d.* to 2*s.* 6*d.* each.
Retort, iron, for making oxygen, 10*s.*
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„ jets, 10*d.* each.
„ connectors, 10*d.* each.
Test-tubes, 3*s.* per dozen.

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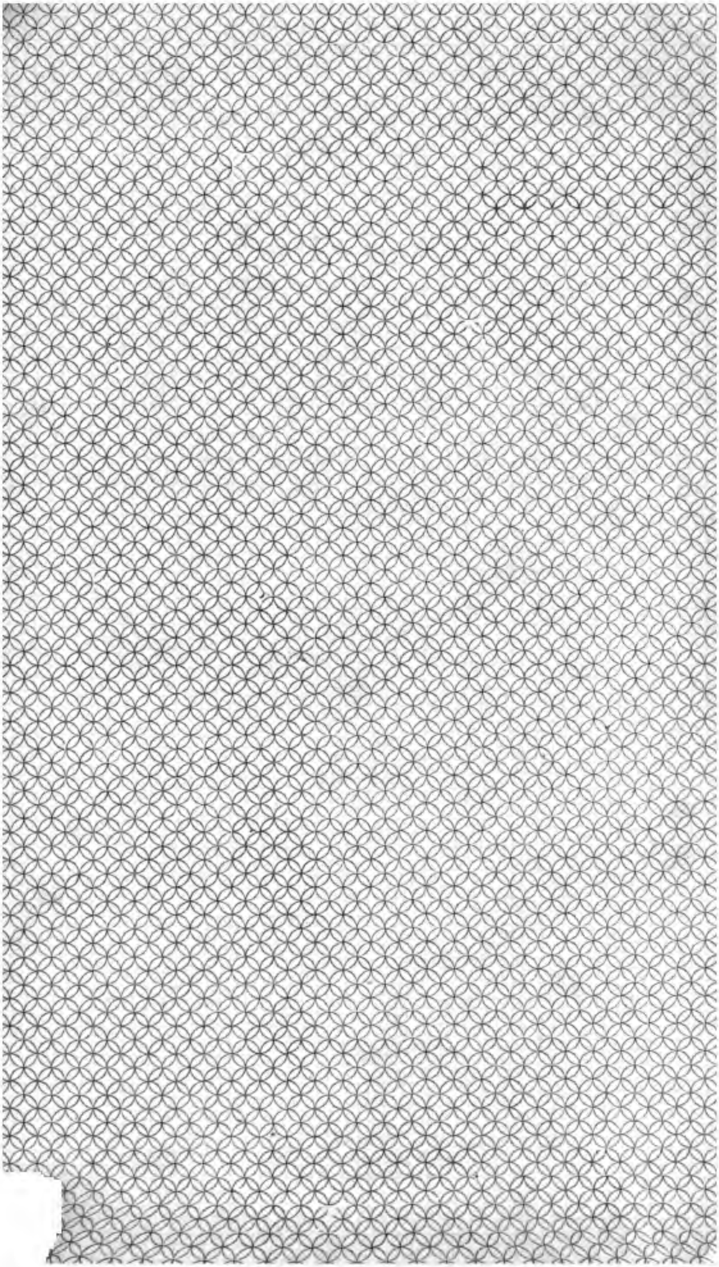

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